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56th Annual Meeting

AUSTIN, TEXAS, June 14–18, 1948

Host

UNIVERSITY OF TEXAS

The Society—A National Forum

By ARTHUR BRONWELL

Secretary of the Society

A survey of the progress of engineering education over the past quarter of a century reveals the vigorous and constructive efforts which members of the A.S.E.E. and its predecessor, the S.P.E.E., have contributed to the advancement of engineering education. Against a kaleidoscopic background, stand out a few clearly defined, monumental contributions which have elevated the profession to a new high point of surveilance, making it possible to obtain a deeper understanding and a greater appreciation of the responsibilities and long-range goals of engineering education.

However, the most significant contributions of the Society are to be found not in the eminent masterpieces, but rather in the functioning of the Society in its capacity as a national forum for the interchange of ideas and the inspiration and stimulus which this has brought to bear upon the manifold problems of engineering education. Every conceivable phase of engineering education has been subjected to critical and constructive analysis through the medium of the Society's meetings, its publications, and through the activities of its councils, committees, divisions, sections, and branches. Out of the cauldron of the past has come a more or less clearly defined plan of engineering eudcation and a sturdy foundation has been laid.

At times, we may feel intuitively that the basic foundation and the framework of our system of engineering education have been so thoroughly planned that little improvement is necessary and we need now concern ourselves only with adding to the superstructure according to the well-defined plans of our predecessors. We may be lured to the conclusion that engineering and the basic sciences have evolved to a quiescent plateau from which there will be continued progress, to be sure, but that the basic pattern of engineering education will remain fixed and immutable; that the task of the future is merely one of improvement and refinement. Even the social sciences and the humanities, those long-neglected segments of engineering education, have been subjected to critical analysis and a solid foundation has been laid for correcting the deficiencies of the past.

What new challenges lie ahead? Can we safely say that the major problems of engineering education have all been solved; that we can now close the books to progress; that we can follow the example of Rip Van Winkle and take a long sleep? If such an attitude had been adopted by the Society and its members a quarter of a century ago, the tragedy of it would be apparent today. No one would deny that there has been a complete reformation

in our whole structure of engineering education during the past quarter of a century—a reformation which was vitally necessary in order that education keep pace with the rapidly expanding frontiers of science and technology.

It is equally apparent that scientific and technological progress today is expanding at a more rapid rate than ever before in the history of mankind. This accelerated progress may be attributed to the unprecedentedly large number of highly trained scientists and engineers, as well as to the increased emphasis placed upon research by the colleges, industry, and government. There can be little doubt that the resulting expansion of scientific and technological knowledge will profoundly alter the engineering curricula of the future. During the past quarter of a century we have seen whole new areas of science and engineering invade the curricula and take a permanent part in our engineering education. In view of the rapid strides of science and engineering today, it is reasonable to assume that the engineering curriculum twenty-five years hence will be as different from that of today as today's curriculum is from that of a quarter of a century ago.

The A.S.E.E. must continue to serve as a national forum for the exchange of ideas. It must continue to serve as a unifying agency through which the members of the Society can exert their constructive influence for the advancement of engineering education. Progress often is marked by two steps forward and one step backward. To assure continued progress in the right direction requires first, a clear definition of the major issues, then a logical, orderly approach to the solution of the problems. It requires discriminating judgment with a cautious observance of the long-range objectives. It requires the efforts, the abilities, and the inspiration of all of those who recognize a keen sense of obligation toward their profession.

Texas Awaits You

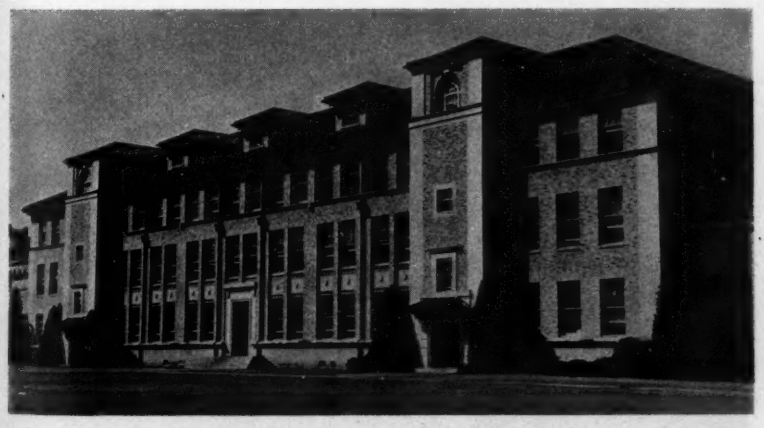
A typical Texas "Howdy" and a warm handclasp await members of the American Society for Engineering Education attending the Society's 1948 annual meeting at the University of Texas next June (14–18).

Located in Central Texas in the capital city, Austin, the University is the capstone of the Lone Star State's educational system. Opened in 1883, it is the largest educational institution south of Chicago and east of California.

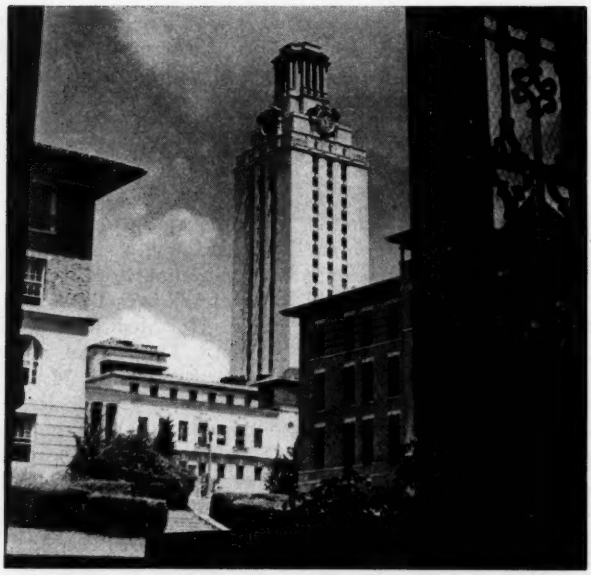
Its College of Engineering was created in 1894. Engineering registration for the current semester is 3,681 students out of a total of 17,343 and is surpassed only by Colleges of Arts and Sciences registration among eight colleges and schools of the Main Campus. Well over 3,000 engineering degrees have been conferred since 1894.

Although the central seat of the University is the Main Campus in Austin its education, research and services spread well over Texas' 263,644 square miles. Its Medical Branch is in Galveston. The Dental School and the University owned M. D. Anderson Hospital for Cancer Research are in Houston. The College of Mines and Metallurgy is in El Paso. It owns and operates cooperatively with the University of Chicago, the W. J. McDonald Observatory in the Davis Mountains of far West Texas. Constitutionally, the Agricultural and Mechanical College of Texas, in College Station, is a sister institution, although governed by a separate board of directors.

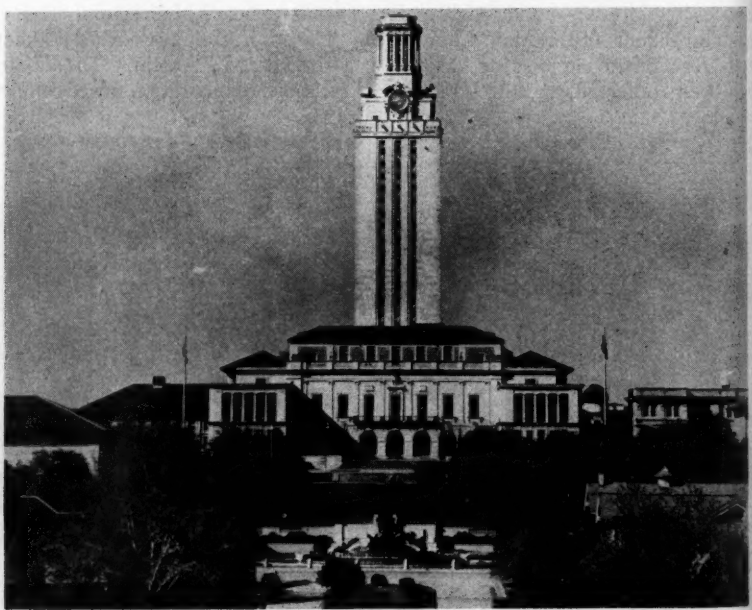
The Main Campus covers 200 acres in the heart of Austin. The 27-story Library-Administration tower competes



Engineering Building, University of Texas



CAMPUS VIEW, UNIVERSITY OF TEXAS, TOWER OF LIBRARY-ADMINISTRATION BUILDING IN BACKGROUND



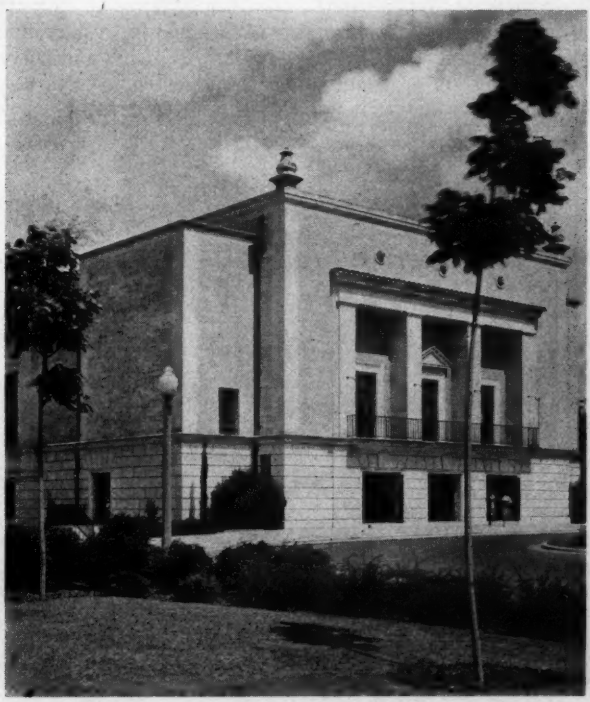
ADMINISTRATION-LIBRARY BUILDING, UNIVERSITY OF TEXAS

with the capitol dome in dominating the city. More than 50 buildings are spread about the Main Campus.

Last year there were 1,023 teachers on the staff, including 835 full-time positions. Approximately 100 full-time positions have been added this year.

The faculty includes many prominent educators and scientists. Administrative head of the University is Dr. Theophilus S. Painter, eminent geneticist and member of the National Academy of Sciences. He was the 1934 winner of the Academy's gold medal as the nation's outstanding scientist. He left the laboratory in 1944 to become acting president and was appointed president in May, 1946. He has been a member of the faculty since 1916. Dr. Painter received his A.B. degree from Roanoke College; his A.M. from Yale and his Ph.D. from Yale. He was awarded an honorary doctorate of science by Yale in 1936. Before coming to the University of Texas he was an instructor in biology at the Sheffield Scientific School.

The University's influence is felt far beyond the borders of its campuses. Through its Extension Division it operates probably the largest program of interscholastic literary, mathematics, music and sports competition in the na-



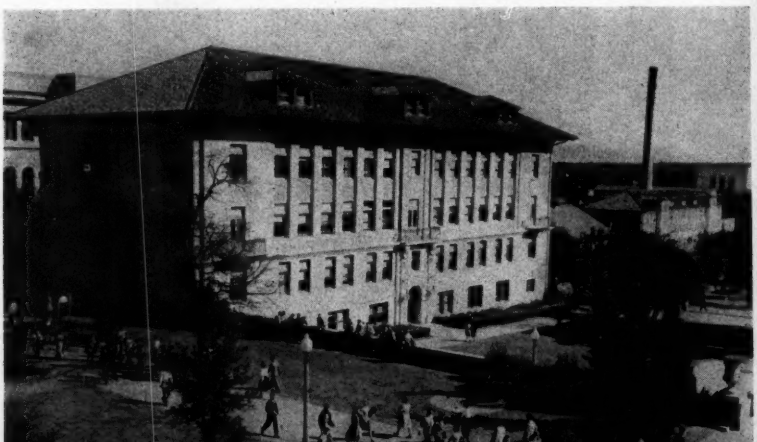
HOGG MEMORIAL AUDITORIUM, UNIVERSITY OF TEXAS

tion. The division also maintains teaching, industrial and business, library and visual instruction bureaus.

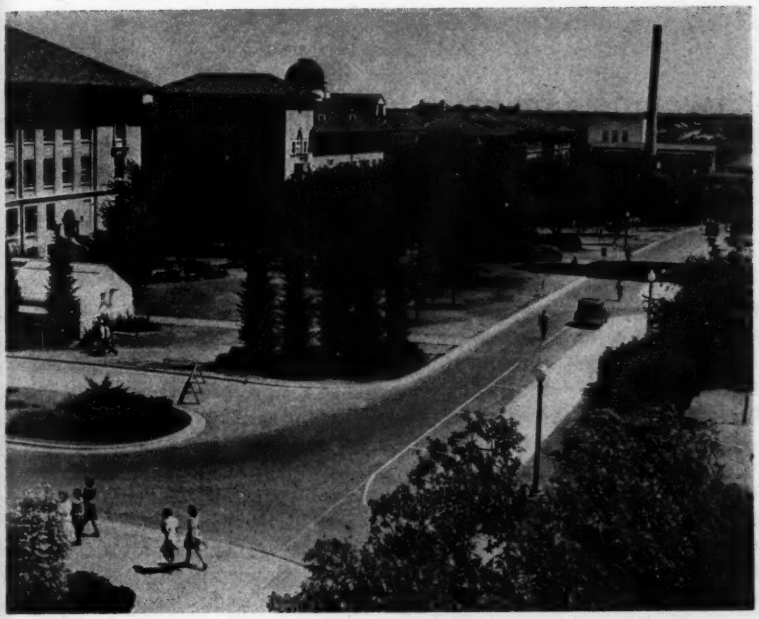
More than 20 organized University research bureaus and institutes serve the state and nation through publications and otherwise. It operates a statewide mental hygiene program and a child health program which are financed by foundations. Radio House, a workshop-laboratory, originates entertainment and educational programs for many types of audiences.

In sports it is a leader in the Southwest Conference and its varsity teams usually are at home among the nation's best.

Financially it is unique. More than 1,000 oil wells contribute to its support and development. The constitution of 1876 set aside a million acres of West Texas land and later the Legislature added a second million acres for a permanent university fund. The land, once thought to be of value only for grazing purposes, later proved to contain oil bearing sands. The income from oil lease sales, royalty and lease rentals goes into the permanent fund. The permanent fund is invested. The income from the investments is divided approximately two-thirds to the University and one-third to Texas A. & M. College. Although the income is increasing the University remains dependent upon legislative appropriations for a large portion of its operating income. Income from the permanent fund is earmarked principally for building and a large expansion program is now being planned. The present plant was designed for a maximum of 8,000 to 10,000 students and postwar enrollment increase has overtaxed it tre-



CAMPUS SCENE WITH GEOLOGY BUILDING IN BACKGROUND, UNIVERSITY OF TEXAS



CAMPUS SCENE, UNIVERSITY OF TEXAS. BUILDINGS, LEFT TO RIGHT: BIOLOGY, PHYSICS, CHEMISTRY AND ENGINEERING

mendously. Temporary dormitories and classroom buildings have been helpful but have not solved the problem of overcrowding.

Veterans account for the large post-war enrollment increase, there being 10,577 enrolled for the current semester. The trend of non-veteran enrollment is upward and may continue until about 1960.

The University's story is a long one, with a thousand ramifications. It includes legends, traditions, political strife. It also includes hospitality and members of the American Society for Engineering Education are urged to sample it to the fullest next June.

Summer's sometimes intense heat has not usually arrived by mid-June. Balmy days and cool nights should be in order. Recreation opportunities will be plentiful. Swimming, boating and fishing are abundantly available within the city limits and in the artificial lakes of the Lower Colorado River Authority system which form a chain running northwesterly from Austin. Plane, train, bus and automobile place Houston, San Antonio and Dallas within easy reach. The Gulf Coast is a few hours distant and Mexico's nearest port of entry, Nuevo Laredo, opposite Laredo, Texas, is 250 miles by highway.

Evening Graduate Programs in Electrical Engineering*

By ERNST WEBER

Head, Department of Electrical Engineering, Polytechnic Institute of Brooklyn

Evening graduate programs have been successful in several metropolitan centers of population which are also centers of industry. Though individual graduate courses had been offered in late afternoon or evening since about 1920, complete degree programs on the Master's level were first introduced at Polytechnic Institute of Brooklyn in 1925 in Chemistry, and in 1928 in Electrical Engineering. The first complete doctoral evening program in Electrical Engineering in the country was offered in 1936 at the Polytechnic Institute of Brooklyn.

According to the latest available statistics published in the January, 1947 issue of the JOURNAL OF ENGINEERING EDUCATION, the enrollment figures for the graduate programs in Electrical Engineering were as follows:

STUDENTS IN E.E. MASTER'S PROGRAMS

	FULL TIME	PART TIME	TOTAL
for the Nation	1189	1474	2663
for Polytechnic Inst. of Brooklyn	46 (3.9%)	209 (14.2%)	255 (9.6%)

STUDENTS IN E.E. DOCTORAL PROGRAMS

	FULL TIME	PART TIME	TOTAL
for the Nation	69	93	162
for Polytechnic Inst. of Brooklyn	3 (4.4%)	41 (44.2%)	44 (27.2%)

Quite different from the situation in the undergraduate programs, we find more students pursuing part time and evening graduate studies than are enrolled in full time graduate work! That a large proportion of the former is found at our Institute is, among other factors, attributable to its location in the heart of the greatest metropolis which is also the focal point of some of the most important research and development laboratories in Electrical Engineering.

This enormous growth of evening graduate programs raises at once the questions of why they were successful and how they might compare with day graduate programs.

It has been the experience that evening graduate courses serve *two purposes*. They either give specialized information in fields of particular interest to men employed in research and development laboratories; or they make possible a combination of gainful employment and study on the graduate level for advanced degrees. Nor-

* Presented at the annual meeting of the A.S.E.E., Minneapolis, June 18–21, 1947.

mally, enrollment at the Polytechnic Institute of Brooklyn has been almost equally divided between these two types of course offerings; more recently, a much larger proportion of students is enrolled in degree programs.

Little need be said about the first type of graduate course serving specialized needs. With a well-selected group of instructors, either from the Institute or from Industry, a high level can readily be set and the enrollment becomes a direct function of the level of the course.

The Evening Graduate School

More should be said about complete degree programs offered in the evening. *Our philosophy* and objectives have been exactly the same as those of any strong day graduate school: training in fundamental methods of analysis, research, and synthesis leading to a critical understanding of the basic principles and a thorough mastery of the knowledge, in a chosen field. As a matter of fact, the generally high caliber of the students has permitted and invited great emphasis upon fundamental courses in mathematics and physics to provide the proper foundation and furnish the powerful tools, for advanced study.

Because of the usually wide experience in laboratory work that the evening students from research and development laboratories bring to the class, the discussion and presentation of the subject matter are kept at a high standard. The students are primarily interested in the basic connecting theory, and in the transition from the theory to the application rather than in any descriptive information pertaining to applications. It is characteristic that these students state preferences for *specific teachers* and select courses frequently because of the teacher rather than because of the subject matter. Training in the professional subjects need not be considered one-sided, because most of these students have had the maturing experience of years of contact with fellow professional men.

Graduate admission proceedings in the evening are, by far, not as critical as graduate admissions in the day school. Keeping the standards high, any weaker student who might have drifted into a class will eliminate himself in very short order. As a result, *the natural selection* will leave only well-qualified students to come up for candidacy for the Master's degree, which, in the usual case, is two years after the entrance of a student into the evening graduate school. Indeed, there exists a rather strong discontinuity in the transition from undergraduate day courses to evening graduate courses which has presented a real challenge even to the best of students continuing directly after graduation from the day undergraduate program.

The *more mature* type of the average evening student makes it imperative to have a faculty with industrial experience which can stand searching questions. In many instances, the student may know more about a specific sector of a field than a teacher; however, the broad background and training of the teacher must make it possible for him to give a satisfactory reply concerning the analysis of the problem, and its relation to fundamental theory. It has been our practice not to appoint any one to the graduate teaching faculty who has not had several years of pertinent industrial experience. On

POLYTECHNIC INSTITUTE OF BROOKLYN

Graduate Program in Electrical Engineering

Basic Course Group

Functions of a Complex Variable I
Transients in Linear Systems
Vector Analysis
Electromagnetic Theory
Advanced Electrical Measurements

Major Course Groups

Electric Power

Power Transmission and Distribution
Theory of Electrical Machines
Power System Stability
Design of Electrical Machines
Advanced A-C Machinery
Advanced Design of Electrical Machines
Servo-Mechanisms
Analysis of Non-Linear Systems
Insulation of Electrical Apparatus

Also selected courses from Mechanical Engineering and from Westinghouse Program

Electronics and Communications

Selected Topics in Electromagnetic Waves
Microwave Components
Radio Propagation and Antennas
Microwave Networks
Network and Filter Theory
Analysis of Non-Linear Systems
Advanced Network Theory
Electron Tube Theory I, II
Electron Optics I, II
Pulsing and Synchronizing Circuits
Broadband Amplifiers
Feedback Amplifiers
Radio Noise and Systems of Modulation
Television Colloquium
Electronic Measuring Equipment
Advanced Electroacoustics
Sound Engineering

Also selected courses from Westinghouse Program

Electrophysics

Introduction to Theoretical Physics
Fundamentals of Mechanics
Statistical Mechanics
Fundamentals of Electron Theory
Fundamentals of Radiation
Quantum Mechanics
Theory of Solids
Modern Methods in Electromagnetic Theory

Also selected courses from Applied Mathematics and Physics

the other hand, an area as rich in prominent research scientists and engineers as New York, allows to draw upon the part time services of outstanding experts in the respective fields for certain specific graduate subjects. This enhances the graduate program, provides interesting contacts for the students, and gives an acknowledged satisfaction to the associated lecturer.

As a natural development of the stress upon fundamentals, close liaison and, indeed, collaboration between the departments of Physics, Mathematics, and Electrical Engineering were established very early. Thus, in 1936, a program of five comprehensive interdepartmental courses in classical and quantum physics was introduced which could be chosen as a major group for the doctor's degree under the heading "Electrophysics." More recently, courses in basic applied mechanics have been added to this group.

Since the time of contact between teacher and class is restricted to a few hours per week, it is very important to amplify class lectures by home assignments requiring extra reading and study. Home assignments should be carefully corrected and returned for resubmission if they were found wrong, or for the student's file if they were found correct. To many students, these problems form an important supplement to the lecture notes.

Administration of the Degree Programs

The administration of graduate degree programs in the evening poses a few problems not present in the day graduate school. Usually, the evening study for the Master's Degree consumes between three and four years, our average being 3.25 years. The Doctor's Program will take, additionally, five to six years of evening study. This makes continuity of effort, contact with the student, freshness of knowledge some of the real problems. It is the more encouraging that the level of actual programs can be kept high. Details of the degree programs will perhaps best illustrate this point.

The *Master's Program* includes as required courses: Vector Analysis to be followed by Electromagnetic Theory, and Complex Functions, followed by Transients in Linear Systems. The course Electromagnetic Theory is taught with full use of Vector Analysis. It presents Maxwell's theory and the basic applications to static field problems, eddy current problems, and radiation problems encountered in research and design practice. The course Transients in Linear Systems reviews classical and operational methods and then applies function theory in connection with Fourier and Laplace Transforms to lumped networks and transmission lines. Of the total of 30 credits required, these prescribed courses constitute 12. Eight additional credits are allowed for thesis, which is required of all students. It must evidence independent and creative thinking and is usually the best index to establish research ability in the case of men interested in going on towards the Doctor's Degree. Upon completion of one-half of the Master's program and before permission for thesis registration is given, the student applies for "candidacy" for the degree which initiates a review of his performance and leads to pertinent action by the program administrator.

The ***requirements for the Doctor's Degree*** beyond those for the Master's Degree include Advanced Differential

Also selected courses from Westinghouse Program

Equations, Analytical Mechanics, and either Statistical Mechanics or Quantum Mechanics. The student must pass a qualifying examination in his major field, which is the field of his dissertation, and he must show satisfactory course performance in two minor fields, usually mathematics and physics, before he can be admitted to "candidacy" for the degree. In order to guide the planning of the student over the long years of his study, a *Guidance Committee* is appointed about one or two years after his completion of the Master's Degree, and after he has been able to definitely select major and minor fields. This Guidance Committee plans and supervises the student's program, taking into account his preferences, his experience, and his previous training. Every doctorand has thus an individualized program of study and personal contact with graduate faculty members which give him confidence of achievement and give us the first hand information so necessary for the higher degrees. It is also obvious that endurance is an important factor in addition to ability.

The greatest stress in the Doctoral Program is, of course, on the dissertation which *must* constitute an original contribution. Where it is possible, we try to induce a student to study his last year for the Doctor's Program on a full time basis as a Research Fellow, in order to concentrate all his effort on the dissertation with only some minor course work. If this is not possible, then arrangements for shorter leaves of absence are usually made to permit the final spurt to the finish.

The scheduling of a full graduate program within the comparatively small number of evening hours available presents a particularly difficult task. Recourse must be taken to give courses in alternate years and, in fact, a few of the top courses might be given only every three years. The magnitude of this scheduling problem can best be judged from the fact that, at present, our graduate program in Electrical Engineering comprises 35 courses, of which 11 are full year courses; to this must be added at least 10 courses each in Physics and Mathematics. On the other hand, to accommodate the large number of graduate students requires many course offerings so as to hold the classes to reasonable sizes and preserve close student contact. The table illustrates this course program.

About Evening Study

Criticism has been made that evening students cannot possibly perform as well as day students since they must be tired after a day's work. If study for advanced degrees in the evening calls for special effort over and above that of the day student, it could only mean that, by laws of natural selection, only the best will endure. Surely, one has to anticipate the many human problems that might temporarily interfere with the pursuit of study, such as marriage, addition to the family and the like. But married students with understanding wives are more conscious of their responsibilities and represent the most serious types of students. It has been our experience that every instructor who comes into contact with our evening graduate student body experiences a more satisfactory response to his teaching, and finds greater challenge in the questions raised than with day students.

There also has been criticism by Industry that men who pursue evening study reduce their effort for the em-

ployer. However, young people will seldom forego all pleasures of life and a long evening of entertainment is surely more detrimental to the next morning's performance than serious devotion to home assignments and study. It has been our experience that upon receiving advanced degrees, students usually find advancement or more responsible assignments in their company; there must, therefore, be some compensation to the employer in the advanced knowledge gained which should make worthwhile encouragement of graduate study for its own sake.

Discussion of Report on Present Day Salaries in Engineering Schools*

By THORNDIKE SAVILLE

Dean, College of Engineering, New York University

The writer was a member of the Executive Committee of the Administrative Council which authorized the investigation by Dr. Jackson and his colleagues, the report which was completed and presented at the June 1947 Annual Meeting of the Society in Minneapolis. When the matter was originally under consideration, it seemed to be highly desirable to have the salary situation in engineering colleges reappraised, particularly when it could be undertaken by such an experienced person as Dr. Jackson, whose admirable report on "Status and Trends in Engineering Education" in 1939 contained comparable statistics with respect to engineering salaries. However, in view of circumstances which have developed since the study was undertaken and completed, I am somewhat doubtful as to its real value at this time. On account of the general salary and wage situation in the United States which has developed during the past two years, and which was hardly anticipated when the present report was begun, I am inclined to think it would have been wiser to have deferred the study for a year or more.

The statistics presented by Dr. Jackson in this report are certainly of current interest, but there is grave question in my mind as to how accurate they are at present, nearly a year after the statistics were compiled. During this year there has been a substantial general increase in engineering college salaries throughout the country. While this doubtless has not kept pace with increases in salaries of engineers of comparable attainments otherwise employed, nonetheless certain of the data in this report may be invalidated as of current applicability. I suspect that engineering college salaries are catching up with salaries on the outside, although they will never catch up fully, and it is questionable in my mind whether on the average this is necessary or desirable for reasons which I shall state.

Dr. Jackson refers to the increasing amount of service which engineering teachers render outside of the academic year, in connection with summer teaching and sponsored research, as well as work with industry and consulting services. He did not comment on the amounts of income thus received, and no information of this sort was gathered on the questionnaires. I think that a very large number of our engineering college teachers do receive such additional compensation, or at any event

*The "Report of the Committee on Present-Day Salaries of Members of Instructional Staffs of Engineering Schools" appeared in the September, 1947, issue of the JOURNAL OF ENGINEERING EDUCATION.

have an opportunity to receive it, and that it represents a very substantial factor in any comparison of the annual compensation of engineering teachers with those of practicing engineers outside of the institution. I see no reason to compare the annual salary received by a man in an engineering college for working 9 to 9½ months with that of an engineer practicing his profession outside who receives an income for 11 or 11½ months work. The college teacher also has vacation periods within the college year which are substantial, including the Christmas and Easter holidays, and time during examination periods and between terms. Furthermore the matter of tenure and security should not be overlooked, as providing additional attractions to the engineer in teaching. The conditions of work are by no means comparable, and therefore the salaries should not be compared without explanation. I think there has been too much of a tendency to overlook these factors in the Jackson report and in certain other reports which have recently come out dealing with engineering college salaries.

Dr. Jackson has recognized this situation, and suggests that information should be developed on (a) institutional policy for payment of supplementary compensation and (b) on procedures for paying staff members who work on contract research for industry or government. I thoroughly agree that such information should be collected and analyzed. I think that the ASEE might well conduct a survey on these practices just as it has done with respect to the base salary situation in the past. We will then have comparable figures with respect to our own profession to compare with those for all professions or other specified professions.

I should hope that perhaps by another year the Association may find it desirable to have Dr. Jackson's data reanalyzed and reinforced by additional information of the sort mentioned above. In fact, on account of the probable greater stabilization of engineering college salaries beginning September 1, 1948, I should like to recommend that in spite of the short time elapsing between reports, we have a resurvey made of the whole salary situation at that time.

Such a study might well include the following specific factors which have a bearing upon the annual income of engineering college teachers:

(a) Base salary, stating number of months service required.
(b) Required teaching load in class hours per week.
(c) Class-hour equivalent of laboratory and design hours.
(d) Number of full time staff in each grade.
(e) Total and average amount paid to each group (instructor, assistant professor, etc.) for (1) teaching outside of period covered by base salary, and (2) work on contract research.
(f) Institutional regulations governing work performed under (e) above.
(g) Institutional regulations governing allowance for time on fundamental unsponsored research.
(h) Institutional regulations governing private consulting work, (a) during period covered by base salary, and (b) during other periods.

I do not pretend to say that engineering college teachers salaries are too low or too high, or that they are

satisfactory. I believe that they should be raised on the average. On the other hand, I do not think we should make specific claims of underpayment by quoting salaries publicly which in the first case are based on 9 or 9½ months employment, and in the second place do not include substantial supplementary income from various sources. Generally speaking, salaried engineers of comparable abilities in outside professional practice do not have opportunities for such supplements to their regular salaries.

Dr. Jackson seems to feel that "if the average salaries at every engineering school approached the values of Chart 11 of mediums of average salaries (for the ten highest paying schools) a much larger proportion of young engineering graduates would be attracted by the possibilities of the teaching profession." However, we must recognize that salaries of all professional employees are generally governed by competition and the general salary ranges in a given geographical area. Certain areas of the country will always reflect higher cost of living by greater compensation than will other areas, and I see no reason in ethics or economics for attempting to have a uniform scale of pay in our engineering schools throughout the entire United States.

The geographical differences in salaries paid in 1946 follows the same pattern as in previous reports. This is natural, and I think indicates possibly two factors. The first is that we should not compare average salaries throughout the United States, and the second is that salaries in certain geographical regions ought to be increased. I suspect (without statistical proof) that the low paying regions are unduly low, whereas the high paying regions are about right. It is indeed possible that some of the institutions in the high paying regions may be paying unduly high salaries at present, since for a year or two the demand has been exceedingly great, and the supply scarce, and some of these institutions have been able to draw upon endowment and other funds precluded to the publicly supported institutions in the low paying parts of the country.

As a matter of fact, quite aside from geographical implications it is entirely conceivable that the desperate scramble and severe competition for personnel among engineering colleges during the past year or so will have admirable results in the future, in that salary scales may be pushed up in the course of the present year to a point where they will be quite attractive when the supply of engineers becomes greater, and the demand less acute. I suspect that salary scales for engineers generally will not increase substantially in the next few years, and that salary scales for engineering teachers will more nearly approach a competitive status with those offered by industry and government for comparable personnel. Indeed I suspect that we are not far from this situation in many parts of the country today.

May I suggest that in appraising the statistical data of this report, reference be made to the Engineers Joint Council report on "The Engineering Profession in Transition" which contains an elaborate study of the salary situation of all engineers throughout the United States for 1946. The data are therefore comparable with those in the Jackson report. One may gain an impression from reading the E.J.C. report that on the average engineering college teachers salaries are not badly out of line with the averages paid for engineering services throughout the country. I do not

wish to take time to go into details, but I think a comparison of the data in the two reports will interest many in this audience.

The report notes that the median of maximum salaries for the professorial group is greater than for the department heads. It is stated this is because three of the ten highest paying institutions do not have permanent rank of department head. It may also be due to the analytical process used by Dr. Jackson in assuming that department chairmen salaries are on a 12 month basis, whereas full professor's salaries are on an academic year basis. Should this be the case (and I am inclined to think it is not true on the average), the rate of compensation of the full professor as compared with the department chairman is even greater. If there is a real tendency in this direction I should hope that what I consider to be an exceedingly desirable arrangement was in effect at a number of institutions, namely that the department head was not necessarily the highest paid member of the department. I think the sooner we get away from the idea that the administrative officer of a department must necessarily be the highest paid man in the department, the better off we will be. More often than not we have to destroy a large part of the genius and scholarly attainments and production of our best teachers and scholars in order to pay them a remuneration which can only be effected by making them department chairmen, thereby swamping them with administrative duties which are burdensome and frequently distasteful. A good department head is certainly to be highly prized, and should receive relatively high compensation. However, I see no reason per se why he should receive higher compensation than a noted teacher and scholar.

Finally, may I comment briefly upon the concluding remarks of Dr. Jackson. These consist in part of quotations from an article by Professor Sumner H. Slichter of Harvard which was published in the *Bulletin of the American Association of University Professors* in the winter of 1946. It is stated in the Jackson report that Professor Slichter's observations are based upon "a study of the returns from 88 colleges and universities." It think it might be well to point out that the study by Dr. Slichter was based solely upon the minimum salary of full professors at the 88 institutions involved. No other information was requested and no other information was given. Accordingly, analysis of the conclusions which are given in the report ought to bear this statistical fact very clearly in mind.

Several of the comments at the end of Dr. Jackson's report seem to me to be intended as conclusions, and indeed were originally reported as such, but actually have little to do with the factual material of the report itself. These comments deal with internal administration of engineering colleges and of universities in general. Inasmuch as the report did not analyze the administrative and budget making policies of the colleges under study, the remarks relating to these subjects would seem to me to be somewhat extraneous to the subject matter of the report.

May I perhaps be permitted to anticipate a little the remarks of the next speaker, especially as I am largely responsible for his appearance here. When I was asked to discuss the Jackson report I stated that I would be glad to do so briefly, but that I thought constructive suggestions relating to procedures for the establishment of grades

and corresponding salaries would be more to the point. I therefore suggested that Professor Lilly of Swarthmore be asked to address the Administrative Council for the reason that he has been making some very unique studies in connection with the Committee on Salaries of the American Society of Civil Engineers. His studies relate particularly to salaries in the engineering teaching profession, and while I have not agreed altogether with his tentative conclusions, I do feel that his method of attack is novel and stimulating. If it can be developed with the help of agencies such as the Administrative Council of ASEE so that it can be generally applicable throughout the country for establishing yardsticks for measuring the various factors which enter into salaries and ranks, I think we shall have taken a very substantial step forward. To my mind it is rather an Utopian idea at present, but the more I have seen Professor Lilly develop his thinking in this matter, the more I have felt that ultimately he may produce an exceedingly useful method of analysis, which if properly used and interpreted may not only assist in the establishment of adequate salaries for engineering teachers, but will be of substantial assistance to engineering college administrators in establishing salary scales. If we can develop some procedure for discovering and rewarding good teachers, as contrasted with the more readily apparent worth of research, we may be able to counteract a tendency which I believe is unfortunately too prevalent at present, whereby many administrators are rewarding faculty members for research and overlooking the equally or more important function of inspired teaching because it is more difficult to appraise.

A Common Field of Graduate Research in Engineering[1]

By O. A. HOUGEN

Professor of Chemical Engineering, University of Wisconsin

"In some fields of engineering practice little or no premium is attached to graduate studies in advanced technical subjects. In the practices of mechanical design, construction, contracting, and plant operation it is generally conceded that the most suitable training, following the bachelor's degree, is secured on the job under the guidance of expert engineers and through the pressure of practical performance. After the bachelor's degree the value of practical experience in the foregoing fields more than offsets the possible gain secured by further technical studies in college. There is a possible risk that too many years of academic training may jeopardize the acquisition by the young engineer of confidence which can best be gained during the formative years. Furthermore, in certain fields the University can ordinarily not afford the faculty nor supply the necessary motivation. The most successful engineers in these fields have secured their advanced training under guidance of experts and under the pressure of the job and the necessity of successful performance." [2]

On the other hand, in the fields of process design there has developed an urgent demand and need for engineers trained in graduate studies leading to the master's and doctor's degrees. The research and technology underlying modern process design call for the combined skills of every branch of engineering. I have designated this as a common field of engineering research, the topic of this paper. In process design the demand for advanced training is as acute today as it was for undergraduate training thirty years ago.

Meaning of Process Design

By process design is meant the engineering research and planning that go into the development of a production or manufacturing operation. Process design is to be distinguished from mechanical design. Mechanical design involves the design of the constructional details of equipment, machinery, and buildings. Process design deals with the selection and specification of process equipment, with plant-layout according to process flow charts, with establishing the proper size and shape of reactor vessels, and the most favorable and economical conditions of operating each apparatus with respect to all variables. Process design is centered about problems of rates of mass

[1] Presented at the Conference of Graduate Studies, A.S.E.E. Annual Meeting, Minneapolis, June 18, 1947.

[2] Parts of this paper in quotations have been taken from the report of the Planning Committee of the College of Engineering, University of Wisconsin, June 5, 1947.

and heat transfer and of chemical change. These production rates are frequently classified under the two categories of unit operations and chemical kinetics.

It may appear to some that the field of process design is largely the concern of the chemical engineer. Where chemical processes are involved this may be the case, but further reflection will show that research problems in process design involve each major field of engineering and provide a common field of engineering research.

The practical objective of process research is to provide scientific data which will permit the rational design of a manufacturing process with the minimum time and equipment spent in pilot plant studies and to operate the final process under the most favorable and economical conditions with respect to all variables such as feed composition, space velocities, recycling, heat and power requirements, and temperature gradients. The objective is to reduce the time and expense of translating a process from a small laboratory scale to full size plant construction. Frequently many years and hundreds of thousands of dollars are needed for this transition. Lack of knowledge of the principles of dimensional similitude is responsible for many of the failures in attempting to translate laboratory experiments to plant scale operation. Scientific methods of process design are as yet not widespread in industry. In the past chemical plants were constructed from experience by trial and error methods; today such plants are being constructed for stream-line production with balance and proportion and with economy in space, materials and energy as the result of scientific research. The petroleum industry of today is in particular characterized by its employment of scientific procedures in the design of equipment for compact and continuous performance in the operations of heat transfer, fluid flow, distillation, and in the processes of hydrogenation, catalytic cracking, alkylation, and polymerization. Particularly good examples of modern rational design based upon process research are to be found in the production of high octane gasolines, the recovery of bromine and magnesium from sea water, the production of phosphoric acid, and the manufacture of nylon and synthetic rubber.

Training Required for Process Design

The technical knowledge involved in process design includes material and energy balances, mass and heat transfer by convection, diffusion, and turbulence; the flow of fluids through granular beds, packed towers, and plate columns; the separation of materials by distillation, extraction, filtration; the thermodynamics and equilibria of reacting systems, the behavior of catalysts and the kinetics of all types of chemical reactions. These are the factors that determine the size, feasibility, and conditions of economical operation. In process design are also included the selection of materials of construction and problems in instrumental record and control of temperature, pressure, flow rates, liquid levels, feed ratios, and composition. The technical skills required in process design involve a comprehensive training in mechanics, machine design, electricity, thermodynamics, materials of construction, hydrodynamics, chemistry, physics, and mathematics.

"With the growing complexity of industry, with the greater ingenuity required in the processing of our dimin-

ishing mineral resources; with the advancing production of synthetic materials, plastics, and elastimers; with the new developments in instrumental control and analysis; with the new era of electronics, catalytic processing, and atomic fission, the need for broader fundamental training becomes increasingly greater. In this complex scientific age research engineers are required to have some familiarity with many advanced subjects, such as electronics, vibrations, elasticity, advanced hydrodynamics, chemical kinetics, chemical thermodynamics, atomic structure, physical chemistry, and nuclear physics. In branches of process engineering dealing with the food, pharmaceutical, leather, and fermentation industries there is the additional demand for training of the engineer in biochemistry and bacteriology. A broad composite scientific training is often demanded in a single individual who is to undertake direction of research, development, and design in modern process industries."

"It is evident that research in process design calls for training in advanced fields of science which can be obtained best in graduate studies at a University rather than in practice. It is common experience that advanced studies in mathematics and the physical and chemical sciences are rarely acquired by individual studies removed from the pressure of daily class-room assignments."

Common Problems in Process Design

It is evident that the research problems in process development spread into all fields of engineering and call for cooperation among the different departments of engineering. Researches in heat transmission are of common interest in chemical, mechanical, metallurgical, and electrical engineering. The hydraulic engineer may gain ideas from the researches conducted by others in the flow of fluids in distillation columns, tower packings, and granular beds and with the greatest variety of gases and liquids. The operations of evaporation, condensation, humidification, and the processes of refrigeration, combustion, and air conditioning are common to both chemical and mechanical engineers. The chemical engineer has followed the mining engineer in studies and researches on mechanical separation, filtration, sedimentation, settling, flotation, and classification. The mechanical engineer is confronted with the most complicated kinetic problems in the performance of internal combustion engines; to date these problems have been too complex to benefit much from the researches in the kinetics of combustion, but the time for helpful collaboration is at hand. Similarly, the design problems of sewage treatment have been too complex to benefit much from bacteriology and organic chemistry, but these fields will soon be drawn together in more helpful cooperation. In problems of process design the selection of materials of construction is involved with corresponding information on strength of materials and resistance to creep and corrosion. In problems of process design instrumental measurements and controls are required with all the research involved in developing suitable electric circuits and mechanical devices. Similarly, rapid and continuous methods are needed for the determination of chemical composition by instrumental methods using the mass spectograph, spectrophotometer, refractometers, conductivity meters, and other devices.

Need for Graduate Research

I shall close this discussion with a plea for greater emphasis upon graduate work and research in engineering. Today there is a shortage of 17,000 Ph.D.'s in fields of physics, chemistry, and engineering. Even though the greatest financial returns in engineering have come through positions of management and production, many young engineers are attracted by the opportunities for original and creative work in graduate studies and research and are peculiarly qualified for these activities. "If it were not for graduate instruction and research in our colleges and universities less advance in fundamental principles and theory would be made and fewer new scientific principles would be developed, progress in some directions of science would mark time. For its source of fundamental principles engineering has drawn largely upon the researches of advanced students in physics, mathematics, and chemistry. But even in the engineering applications of these theories there would be little progress without additional research and studies. Textbooks and handbooks would not exist or would soon become obsolete if it were not for the pressure of advanced studies and research. Engineering colleges with no graduate or research programs must lean upon others for professional advancement. Without graduate work and research, courses become sterile and repetitious. Engineering courses should be in a continuous state of flux with discard of that which is obsolete and replacement with the new. There is the danger that professors without research or consulting activities, or without contact with industry, research and graduate students soon become out of date. There are instances where theories long outdated are still being taught to the exclusion of modern theories. Without the stimulus of research and graduate studies, it is difficult to keep pace with the development of engineering principles."

The benefits of graduate studies and research rapidly leaven and enrich the work of undergraduate instruction, forcing out the old and bringing in the new. "The effectiveness of undergraduate instruction is usually determined by the interest and capacity of the instructor. An instructor who himself has not had experience in research and graduate studies is not well qualified to guide others in these directions. The value of graduate work and research should be recognized in the appointment and qualifications of the faculty."

"In fundamental engineering research the engineering faculty should lead and not wait for industry to take the initiative. Industry looks to the university for enlightenment and guidance in the advancement of theory. Industrial leaders and engineers are too preoccupied with the problems of production and profit to keep in touch with theoretical developments and do not recognize the value of theory until demonstrated in practice. In the past, practical applications have followed the discovery of scientific theories often by hundreds of years. Today the gap between theoretical advances and practical applications has become short. Indeed the curtailment of theoretical research during the war nearly closed this gap between the stage of scientific knowledge and its application. With the expansion of industrial research laboratories and increasing recognition of the value of research, the need becomes even more acute for the colleges of engineering to engage in fundamental research and to train students in advanced theories."

Education and Practical Training of Mechanical Engineers in the United States*

By ROBERT E. DOHERTY
President, Carnegie Institute of Technology

It gives me pleasure to bring to the Institution of Mechanical Engineers, on the occasion of its Centenary celebration, warm greetings from engineers and educators in the United States. I count it a great honor to participate in the program and discuss with you the education and practical training of mechanical engineers in my country.

The route by which mechanical engineers, during the past 75 years, have reached professional competence has of course undergone evolution from the beginning—slow on the whole, but seeming now to be on the threshold of more rapid development involving some new directions. This evolution, as regards formal college education, has been from a dominant emphasis upon practical training in the early days, toward greater emphasis upon the scientific foundation which underlies mechanical engineering and upon the economic and management phases of engineering activity; and, as regards the process of acquiring practical experience in industry, it has moved from an unplanned program of on-the-job experience towards more purposeful schedules to this end. The new turn which this evolutionary movement is now taking involves not only further progress towards the ends I have just mentioned, but also a fundamental revision of the concept of the engineer as a professional man, and therefore a corresponding revision of his educational requirements.

I shall discuss formal college education in the paper itself, and practical training in the Appendix.

Education

Present status and trends in education may be understood better if, as it were, we compare two points on the curve —say 25 years ago and now—and then examine carefully the slope at the second point. We shall compare these two points in terms of the requirements for the B.S. degree in mechanical engineering, status of graduate work, growth of specialized curricula, influence of the profession, enrollments, technical institutes, etc.

From the early programs established about 1870, formal education moved along the lines I have just drawn, the movement toward the basic sciences being especially marked after 1890. The appearance of the electrical engineering curriculum in the 1880's, and later of chemical engineering—both of which had sprung from science curricula—naturally influenced the evolution of the mechanical engineering cur-

*Address delivered at the Centenary Celebration of the Institution of Mechanical Engineers, London, June, 1947.

riculum, which itself had sprung from more practical beginnings. At our first point, some 25 years ago, the representative four-year curriculum in mechanical engineering, leading to the Bachelor's degree, was, so far as subject matters are concerned, roughly as indicated in the first column of Table I.[1]

TABLE I

REPRESENTATIVE REQUIREMENTS FOR THE B.S. DEGREE IN MECHANICAL ENGINEERING

Subject	Required Semester-hours 1923	1946[2]
Mathematics	16	16
Physical science	19	23
Humanistic-social	13	22
Mechanical engineering	53	42
Other engineering	39	30
Miscellaneous	10	4
Total	150	137

(Totals do not include military—and physical training)

The second point on the curve is indicated by the 1946 column. Comparing these columns, we find, first of all, a reduction in the over-all requirements. As to the components, one finds no change in mathematics, a small increase in science, but a reduction in engineering subjects to make room both for an increase in humanistic-social subjects and for the general reduction. Despite the former, the foreign language requirement was reduced. The amount of shop work in the curriculum was decreased.

Other educational trends between the first and second points are not explicit in Table I. In 1923 industrial management had become a recognized area in the field of mechanical engineering. By then 17 engineering schools—roughly 12 per cent of the total—had established special curricula in this area. The trend continued during the next 25 years, so that now 29 schools [3] have such curricula approved —or, as we say, accredited—by the Engineers' Council for Professional Development.[4]

There has also been a trend toward a multiplicity of specialized curricula and courses. The advances of science and the tremendous increase in the scope of its industrial applications have of course brought newly defined specialized industrial fields. These changes have been reflected both in the organization of the profession and in education. Mechanical engineering has not escaped. For example, in the profession [5] there are now separate

[1] Wickenden Report, S.P.E.E. Investigation of Engineering Education, 1923–29, averages from data on pp. 482–484.

[2] Averages based on data from catalogues of the following institutions: Cornell University, Massachusetts Institute of Technology, Pennsylvania State College, California Institute of Technology, University of Illinois, Carnegie Institute of Technology, Lehigh University, Illinois Institute of Technology. All of these except California Institute and Illinois Institute are represented in first columns. Mathematics: at least through integral calculus. Physical science: at least elementary physics and chemistry. Humanistic-social: principally English and economics, but also such subjects as history, foreign language, business law. Mechanical engineering: subjects given by mechanical engineering department. Other engineering: subjects such as electrical engineering, mechanics, engineering drawing, etc. Semester-hour: one hour per week in class for one semester—a term of some 18 weeks.

[3] Engineers' Council for Professional Development Report, 1945, p. 25.

[4] A conference, created in 1932, of 3 representatives each of six engineering societies (including the Engineering Institute of Canada), the engineering educators (S.P.E.E.), and the National Council of State Boards of Engineering Examiners.

[5] C. E. Davies, Organizations of Engineers in United States, International Technical Congress, 1946, p. 5.

organizations in the following fields: heating and ventilating, automotive, aeronautical, refrigeration, agricultural. In education, these and other related fields are represented in special curricula.[6] And the number of specialized individual courses is almost beyond count.

Another significant change has been the great increase in graduate work. In the early 1920's fewer than 100 advanced degrees were conferred annually in *all* branches of engineering, and practically all of these were the Master's degree. In 1940 there were 1329 Masters' degrees and 108 Doctors' degrees, of which 170 Masters' and 7 Doctors' were in mechanical engineering. In 1946 there were 1036 Masters' degrees and 82 Doctors', of which 178 Masters' and 10 Doctors' were in mechanical engineering.

Professional influence has of course also been felt. The Society for the Promotion of Engineering Education [7] has been most influential in bringing about a clear formulation of purpose and in encouraging engineering teachers to adopt it, as indicated later. One of the primary functions of the Engineer's Council for Professional Development is to accredit curricula in engineering. In the 1920's there were some 150 colleges offering curricula in engineering. In spite of the great increase in students, the number of such colleges has not increased, and only 133 of them have accredited curricula. Another result is the definite restraint by this Council upon the continued multiplication of specialized curricula. The American Society of Mechanical Engineers has also been influential by bringing practicing engineers and college teachers together in conference. State laws require that practicing engineers be registered. Qualifications for registration are represented in E.C.P.D.'s programs.[8] And, of course, the increasingly exacting professional requirements of industry have had their effect.

There has been a growing tendency, especially in view of experience in training technical personnel during the late War, to recognize the important role which technical institutes —roughly similar to the local technical institutions in England—should play in the whole scheme of technological education. In order to assure a better balance between the roles of the engineering college and the technical institute, the E.C.P.D. has now undertaken the accrediting of these institutes.[9] Also, an increasing number of junior colleges have offered elementary courses in engineering.

Another strong trend has been the increasing percentage of practicing mechanical engineers who are college graduates. It is estimated that 80 per cent of the present membership of A.S.M.E. are graduates, and 97 per cent of the new members.

And finally I mention the increase in enrollment. In 1922 there were 56,649 enrolled in engineering colleges; in 1940—the last prewar year—110,618, of whom 28,600 were in mechanical engineering; and in 1946, an abnormal year, over 200,000, of whom some 43,000 are in mechanical engineering. Large numbers are temporarily appropriate, in order to offset the

[6] Annual Report, Engineers' Council for Professional Development, List of Accredited Curricula, 1945, p. 23.

[7] Now the American Society for Engineering Education.

[8] E.C.P.D. Annual Report, 1945, p. 31, Definition of an Engineer.

[9] Ibid., p. 14, Technical Institute Accrediting Program, H. P. Hammond.

deficit of new engineers due to the War.

Having compared the two points on our curve, as regards formal education, we shall now examine the slope at the second point. What are the educational trends now?

I have said that great changes are now getting under way in all branches of formal engineering education. These are aimed at placing greater emphasis upon fundamentals that lie at the center of scientific and engineering knowledge, and less upon the specialized information and "know-how" that lie at the periphery; and at recognizing social and civic responsibilities, and preparing the student for them, and thus for a worthy personal and professional life. The velocity of change is as yet low, but the acceleration is high.

The new philosophy of engineering education and the formulation of definite objectives were stated in 1940 by the S.P.E.E.[10] and endorsed by the E.C.P.D. The objectives were reviewed and reaffirmed by both organizations in 1944.[11] Although the new outlook had become focused in the earlier Report, it is, I think, fair to say that the recommendations were at first received by engineering faculties with only mild enthusiasm. The War, however, had its impact on educational thinking[12] and brought a more general acceptance of the new outlook. Thus, with this added impetus and the sponsorship of these two professional bodies, in both of which mechanical engineers are represented, this new movement is under debate in every engineering faculty. Many of them have reached the stage of definite planning, and new programs are in effect at some institutions.

The central recommendations of the second S.P.E.E. Report, looking to the implementation of the new purpose, are that "the attempt to make the undergraduate student proficient in specialized subdivisions of engineering practice must be abandoned in the interest of developing mastery of basic principles"; there be greater emphasis upon cultivation of creative ability; the utmost care be exercised in the selection and development of engineering faculties; graduate work of high quality be expanded; instruction and research be developed as complementary and coordinate functions; production management be included as a phase of *engineering* activity; the great importance of the role of technical institutes in the scheme of technological education be recognized; in the division of the student's educational time, not less than 20 per cent be devoted to the humanistic-social studies; these studies be planned so as to constitute "a unified, developing sequence extending through the curriculum."

These recommendations created problems. The four-year curriculum is already crowded without room enough even for scientific and technological subjects. How then could the humanistic-social content be practically doubled? There are two schools of thought. One would lengthen the undergraduate curriculum to five years. The other would cut down specialized courses to make room and let the student specialize on the job after graduation, or continue for one, two, or three years in graduate

[10] "Report on Aims and Scope of Engineering Curricula," *S.P.E.E. Proceedings*, Vol. XLVII, pp. 555–566.

[11] "Engineering Education After the War," *S.P.E.E. Proceedings*, Vol. LI, pp. 589–614.

[12] For further example of direction of thinking, see "Engineering and Human Affairs," Princeton Bicentennial Conferences, October 2, 1946.

work. Four institutions have recently adopted the five-year curriculum—Cornell, Ohio State, Minnesota, Louisville. A few have followed the other course. The rest are struggling with the problem. It is a stubborn issue.

Another is the related long-run *versus* short-run issue. Should education prepare the engineering student for continuing professional growth or for immediate proficiency in engineering routines? In other words, should more of his time be devoted to a mastery of fundamentals and less to specialized study, or the other way around? The S.P.E.E. Reports, endorsed by E.C. P.D., are clear on this point: prepare for the long pull. But the pressure from small industries is opposite. Most of the large manufacturing industries, however, favor the S.P.E.E. proposal.

Still another critical problem is the shortage of qualified teachers, and this problem is now aggravated, and others created, by the overwhelming student enrollments. Thus, engineering educators in the United States have their hands full.

May I now venture a personal view. The need of America—indeed of the world—goes far beyond mere technical requirements in engineering education. Especially in a democracy, and again in a complex technological age, the need of disciplined professional intellects that can recognize and cope with the great issues of our rapidly evolving civilization, transcends all other needs I know. And this need is pointed directly at the engineering profession which, with the scientists, has had increasingly great responsibility for the drastic changes in the human environment and hence also for competence of its members to foresee and to deal with the social and economic consequences of their work. The solution of such social problems cannot be left wholly to other professions, as history shows; it challenges the best that all of them can do. Engineers must do their part.

It is the job of engineering education to prepare them to do so, and to this end, as well as for competence in the strictly engineering side of professional practice, I recommend the following two principles:

1. The primary function of formal professional education should be to equip the student to use in subsequent learning and in professional work, an understanding of the fundamental concepts, principles, techniques, and ways of thought of his profession in order that he may develop throughout life in analytical and creative power.

2. Education for citizenship and good individual living should be an integral part of professional education and must not be separated from it. Such education includes assisting the student to develop a philosophy of life and firm sense of social responsibility, and to acquire the basic knowledge and skill necessary to apply to present-day social problems, the realistic, incisive, and well-ordered thought that characterizes good professional thinking.

Let me say that the formal education of mechanical—and all other—engineers in the United States is meeting the challenge of the times. It is late; there is a great lag between all professional education, including engineering, and the needs of society. Social unrest, the stubborn issues between labor and management, and other dislocations that now bedevil us are clear evidence that this lag must be eliminated as soon as possible. The hope is that the intensive attention now being given to pro-

fessional education will close the gap before it is too late.

In conclusion, I hope that I have left with you the clear impression that engineering education in America is informed with a new purpose—a new concept of the engineer as a professional man—and is pressing ahead to accomplish that purpose; and that in practical training, industry is learning the value of a planned program of "internship" and an increasing number of companies are adopting it. And also let me say again that I am gratified at being privileged to participate in the Centenary celebration—all the more so because such meetings tend to bring your country and mine still closer together.

Appendix—Practical Training

The following question was answered by ten manufacturing companies, representing such industries as steel, aluminum, automotive, electrical, aeronautical, machine, and fabrication: How does the college graduate who comes to the company acquire the practical training and experience necessary to become a mechanical engineer?

The replies indicate plans that, of course, differ from each other, but there are a few common elements. In all, the college graduate must serve an "internship" to acquire the necessary practical training. Most of them have definitely scheduled programs, and some have highly developed plans involving class work paralleling the shop or drafting room experience. Certainly the trend in large industry is toward a planned program.

Another method is the "cooperative" plan[13] between college and industry in which the student spends alternate periods on the campus and in the plant. This plan is on the increase. In 1925 there were 16 such plans; in 1941, 33.

The plans of practical training in industry are outlined in the following statements:

Aluminum Company of America

During the first few weeks following employment by Alcoa, the mechanical engineering graduate enters a planned training program starting with an orientation course. This includes discussions of the company's history and background, of its products, of the relationship between the line and staff engineering departments, and of the general functions of the operating, metallurgical, engineering, and administrative departments. During this period he may be assigned to various staff departments such as production planning, metallurgy, and industrial engineering, or to some operating department (sheet, extrusions, etc.) where he can observe these activities "firsthand."

Following this orientation period he is assigned to a senior engineer under whose guidance he first performs a wide variety of relatively simple jobs before taking part in general plant mechanical problems. His work on these general plant mechanical problems serves as an indication of his capabilities and future possibilities.

Finally, under the guidance of a senior engineer, the engineering graduate is assigned to specific engineering problems, where he learns the practical application of engineering to specific operating problems, and is then on his way towards becoming a full-fledged mechanical engineer.

Blaw-Knox Company (Machinery and Steel Products)

This company's flexible plan permits each division to develop its own program of practical training.

In the foundry and machine division, for example, the young engineer receives his training in three periods

[13] "Cooperative Education," *S.P.E.E. Proceedings*, Vol. LII, pp. 395–399, 1944.

First, he learns the product by checking drawings and later detailing equipment under close supervision by an experienced engineer. He spends increasingly more time in the shop, observing and checking the assembly of equipment he has helped to engineer. The second period is outside. Accompanying an experienced engineer, he observes the actual operation of equipment in the field and talks with the men who operate it, thus learning their constructive criticisms. In the third period he assists in smaller installations and the initial operation of equipment. Thus, after several years, he becomes useful in creating new designs and is placed on larger and more complicated equipment.

In another division (steel fabrication) success has been found along different lines. In contrast with the old method of placing the graduate engineer at the bottom, *i.e.*, tracing and detailing in order to teach him the company products and the application of his college training to practical engineering, we have proved that, if charged with some responsibility of design, under high-grade supervision, he can do productive work of a much higher degree during this training period.

Therefore, the young engineer receives regular engineering design assignments in which he meets practice, and learns the engineering principles and formulae which fit the problem at hand. Regularly scheduled trips to the shops familiarize him with the various machines and processes and their functions. He also may learn some "tricks of the trade" from the shop men, so that these shop trips are "education from observation."

Our policy of providing an opportunity for the young engineer to see the results of his efforts is one of the most important phases of his training. When a machine or structure on which he has done design work is completed, he has a chance to see it in operation or erected.

Boeing Aircraft Company

In the Boeing Aircraft Company, practical training for many engineers begins on the drafting board. Indeed this should be the first step for all young engineers—it is the principal means by which any engineer puts his ideas into concrete form. Whereas the young engineer may spend most of his time on the drafting board, as he goes up the scale his work generally becomes less and less design and more and more supervision. However, moving up the scale on the side of supervision requires an increasing understanding of human relationships, based on practical experience and on study. In developing an engineer, it is essential that the man not be forgotten. An understanding of the relationship between design and production is important in training good designers. An understanding of the problem of the shop man expedites more workable design and more economical production. This practical training and practical understanding are achieved by the young engineer through close and continuing contacts with the factory operations which are involved in producing the parts he designs, and in dealing with men in the process.

Carnegie-Illinois Steel Corporation

A mechanical engineering graduate receives training and the opportunity for education throughout his business connection with this company. In general, he secures this by graduated assignments in keeping with his ability, by observation and analysis of the various processes and mechanical equipment, and by assimilating the experience of specialized engineers.

To expedite the process this company has set up indoctrination schedules for the young graduate in the majority of our plants and departments. This schedule usually involves intra- and inter-departmental training, to provide an understanding of the work performed in each department and its relation to the

whole. Minor odd jobs are assigned the trainee in each group responsibility. After a year or two of apprenticeship training the young engineer usually develops a particular aptitude, and he is given a more permanent assignment. His career is carefully followed, and an effort made by management to move him laterally or vertically, as the opportunity presents, to enhance his training.

His early training includes regularly scheduled group discussions and conferences. Educational courses given by competent company engineers enable the young, as well as mature, engineers to receive special knowledge concerning engineering design of various plant facilities; engineering sales and forecast; technological development and research; the business of engineering, traffic, and transportation; metallurgical and methods engineering. Many of these courses are conducted in affiliation with colleges in a program leading to an advanced degree. Such courses provide the opportunity to discuss, face to face with our leading engineers, problems inherent in our industry; to meet associates, key men, and executives of the plant and general offices on common ground; and to acquire a broad perspective of the company's business.

Caterpillar Tractor Company (Diesel engines, tractors, motor graders, earthmoving equipment)

This company has a highly organized training program. There are two plans. One is the cooperative program with engineering colleges, and the other is a one-year orientation program for men who already hold a Bachelor of Science degree.

The cooperative course is conducted in conjunction with either the Illinois Institute of Technology or Northwestern University. The undergraduate spends alternate periods of three to four months in college and in the plant. The trainee learns to operate production machine tools, is assigned a variety of work in the Heat Treat, Foundry, Welding, and Product Assembly Departments. After five years, he receives his Bachelor of Science degree in engineering from the university and is ready for responsible work.

For the company's college graduate orientation program, college graduates of superior ability are selected. The shop schedule includes work on assembly lines and the proving grounds to become acquainted with the company's products, work assignments in engineering design and research to learn how new products are developed, and varied experience in the Heat Treat and Foundry Departments to become familiar with manufacturing procedures.

Class meetings are held weekly on company time. The trainee attends technical lectures and conferences and prepares special reports.

Upon successful completion of this training schedule, the trainee is placed in one of the departments of the company. If further training is required, arrangements are made by the department in which the trainee is placed.

Ford Motor Company

Last year, the Ford Motor Company hired approximately fifty graduate engineers. The one-year training program started with a two-week tour of the Rouge Plant area, under the guidance of the Safety Department. This offered an opportunity to become familiar with the various buildings and the phase of manufacturing accomplished in each. Then the men spent a period of time in every phase of manufacture of the automobile, from the blast furnace and steel mills through the final assembly line. The training in these departments consisted of actual work side by side with production workers, as well as discussions about operations and procedures with supervisors and training representatives. At the end of each period, the student engineer was required to write a comprehensive report of that phase of manufacturing.

In addition, the men spent time in the various service functions connected with the manufacture of automobiles—such as time and motion study, electrical maintenance and repair, process engineering, powerhouse, and the Dearborn Engineering Laboratories where our testing, development, and research activities are performed.

Upon completion of the training, these men were placed throughout the various departments of the company. We have learned that this training has benefited them greatly in successfully performing their first job assignments. We do not feel that this program alone trains a man to be a qualified mechanical engineer. However, his education, a year of training, actual job assignment, and continued study in his chosen field of specialization should contribute to the attainment of his goal.

General Electric Company

The general plan for practical training of college graduates includes two steps: a year or so in the factory, testing manufactured apparatus; and then practical experience in an engineering department. These steps are paralleled by numerous special programs for special groups.

During the first step the trainees have successive three months' assignments in different manufacturing sections; in each they first help with, then have full responsibility for, the tests. They also act as engineering inspectors. After each assignment they are rated on ability and personal qualities.

The second step is in the engineering departments, where the foremost requirement is that the young engineers be placed on interesting and important work and be supervised by a good leader. They must realize that this work is being carefully watched and recognized; have opportunity to learn about the whole job, not merely a specialized part; be given as much responsibility as possible; and see an outlet for future advancement.

The plan is designed to meet these requirements. As examples, merit ratings, on which salary is based, are made on performance in their assignments, which include all phases of design and manufacture. Also, in a special course conducted by the men themselves, they learn from each other the work of the whole division.

An example of special programs is the Creative Engineering Program, planned to discover and develop creative ability. Some thirty young men are selected each year through personal interviews. Hobbies, knowledge of engineering fundamentals, curiosity about design, ability to recall and make use of experience are considered.

The program includes class work to stimulate creative interest, together with engineering assignments under supervision of experienced creative engineers.

Mesta Machine Company (Special equipment for the steel—and nonferrous industries)

Normally, we carefully select each year for training six or eight engineering graduates. They are first placed on assembly work for a period of at least one and one-half years, under the guidance of our Apprentice Training Instructor, where they become familiar with the machinery we produce and gain practical experience from testing.

This first assignment serves also as a selective process. At the end the group is divided according to ability and interests. Some are placed in shop work, with the opportunity to become general foremen and supervisors; some in sales and engineering departments; and some in the engineering department.

Here they are classed as engineering apprentices. In addition to practical training on the drafting board, they are assigned, when possible, to outside installation work or to be observers where trouble may develop in the operation of mill equipment.

After three years they are given the rating of Junior Engineers. Their work and compensation depends subsequently entirely upon their initiative and ability.

These young men are making good as foremen and other supervisors, and as engineers, and they agree that the compensation and practical experience gained during the training have been quite satisfactory.

North American Aviation, Inc.

Because of an increasing flow of experienced personnel during the last year, our present preliminary training for new engineers, including college graduates, consists of an orientation course only. This comprises a study of plant organization, structure, flow, techniques, and other fundamentals which enable the incoming employee to fit into the organization more quickly. The study of actual problems, lectures, and motion pictures illustrating shop methods and processes, are included for engineering draftsmen.

After original orientation, further training is gained by experience. Graduates are given ample opportunity for contact with manufacturing departments and for expanding their knowledge of plant methods and procedure. Under careful supervision, more responsible assignments, planned to broaden their technical knowledge, are made as rapidly as feasible. Under this system the majority of our engineering graduates progress steadily.

However, we have found that most engineering graduates are not sufficiently well-grounded in the fundamentals of our work, and we believe that, in the future, industry will expect the graduate to be better equipped with practical training before hire. Further use of cooperative systems, planned vacation work in industry, and more required practical courses would aid substantially in successful placement. Such preparation, which makes the graduate more immediately productive and reduces training time, is becoming an increasingly important consideration in employee selection.

Westinghouse Electric Corporation

All young mechanical engineering graduates take the Graduate Student Training Course consisting of the following:

1. Orientation—one week.

2. Several six- to eight-week basic work assignments in Westinghouse plants such as the Aviation Gas Turbine, Steam, Stoker, and Air-Conditioning divisions. There the engineer works in production, inspection, and test departments, gaining a picture of the steps involved in the building and testing of equipment.

3. Eight 40-hour weeks of class work in fundamentals of Westinghouse engineering design and application. Conference leaders for each major type of apparatus under consideration are specialists in the design and application of that apparatus in their respective fields.

4. Men segregated to engineering department work then attend the Engineering Principles and Procedure School for two weeks. The subjects covered include the Functions of an Engineer in a Division, Westinghouse Drawing System, Manufacturing Information, Patents, Westinghouse Research Department, Technical Article Writing, Engineering Report Writing, Engineering Technical Societies, and Application Engineering.

5. A group of these men, selected by competitive examinations, attend the Westinghouse Mechanical Design School for a period of thirteen weeks. The subjects covered include Applied Mathematics, Theory of Elasticity and Strength of Materials, Dynamics and Vibrations, Fluid Mechanics, Thermodynamics and Heat Transfer. The young man is then given several six- to eight-week assignments in engineering departments leading to final placement.

Further opportunity for advanced technical training is afforded through the Westinghouse Graduate Study Program, offered in cooperation with several leading universities. Through this program, technical men at key Westinghouse locations may take evening engineering courses leading to Master's and Doctor's degrees.

Administrative Policies and Objectives of Research in Engineering Colleges*

By FREDERICK E. TERMAN
Dean of Engineering, Stanford University

Research of the sponsored type, such as now available, presents a challenging opportunity for schools of engineering to advance the professional status of the engineer and of engineering. The opportunity lies in integrating such research properly into the teaching and training activities of a university, so that it becomes academic research.

The objectives of academic research should be:

(1) The development of the highest type of trained men. In this connection one takes note of the fact that in the current shortage of scientifically trained personnel, nowhere is the shortage as severe as in the category of *engineer-scientist*.

(2) The further training of men already on teaching staffs. This applies to young men having real promise, but whose formal academic training is inadequate to enable them to realize their full possibilities as outstanding teachers and leaders in academic activities. This is of crucial importance because it is obviously impossible to train men in any substantial numbers to a level higher than represented by the training and knowledge of the teachers.

(3) Keeping faculty members interested in current progress, i.e., preventing them from going to seed.

(4) The advancement of engineering as a science and the raising of the professional status of the engineer. This point is elaborated upon below.

(5) The advancement of knowledge. This is placed last because it is an objective by definition, *i.e., if it is research it is advancement of knowledge*. In this connection it is to be noted that not all that goes by the name of research is advancement of knowledge.

Returning to Item (4), if the situation is realistically faced, we must agree that the present position of engineering in academic circles leaves much to be desired, particularly in schools having strong departments of natural sciences. Under such conditions engineering tends to be looked down upon as a necessary but not one of the higher activities. To use a mixed metaphor, among the sciences the social standing of the engineer is low.

Unfortunately, there is considerable justification for this situation, particularly in civil, electrical, and mechanical engineering, even though the situation is now rapidly improving. The length and breadth of systematic formal training, and the broad scholarly standards representing the minimum requirements that teachers of engineering must meet, are on the average considerably less rigorous than those required for corresponding academic positions

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in chemistry, physics, mathematics, biology, psychology, etc. In particular, although teachers of engineering are almost universally well grounded in the subject matter that they teach in *undergraduate* courses, they are far too frequently very inadequately trained in the fundamental science in which this subject matter originates. Again, only a very small percentage of the best engineering students, except those in chemical engineering, carry their studies far enough beyond the bachelor's degree to obtain a training comparable in depth and breadth with that received by the more promising young physicists, chemists, etc.

A review of the engineering developments of the war shows that the engineer failed in many ways to measure up to the needs associated with new fields of engineering activity. For example, in electronics the creative engineering that led to the remarkable array of new tubes, circuits, techniques, and systems that are the basis of the present boom in electronics, and likewise the establishment of the fundamental principles of engineering design and engineering analysis associated with these developments, originated in large measure with physicists who temporarily turned to engineering and took over leadership in radio engineering.

Perhaps this should not have been so, but an electrical engineer in the radio field could hardly have been expected to exercise leadership in these new developments that so profoundly changed radio. The typical good young electrical engineer in radio work spent four years in college, and concentrated a substantial part of his junior and senior years learning 60 cycle techniques and practices from professors who were not well versed in the more advanced mathematics and physics pertinent to radio engineering. Our young radio engineer normally had mathematics through ordinary differential equations, and had a few years of industrial experience in association with other similarly trained engineers. In contrast, the well trained young physicist of the same age had devoted seven to eight years to formal college training, knew mathematics through advanced calculus and complex variables, understood the fundamentals of electromagnetic theory which includes 60 cycle techniques, radio waves, etc., as special cases, and had acquired a working knowledge of optics, gas discharge processes, mechanics, thermodynamics, and the structure of the atom, all on a far more fundamental basis than the engineer's knowledge. A man with this type of training pitted against a standard electrical engineer of the same age and equal mental ability naturally won out every time in ability to understand new concepts and to develop their possibilities. Of course the physicist did not know engineering practice to start with, but he picked up what he needed to know very rapidly, whereas the engineer could not with equal ease acquire the basic scientific fundamentals that he lacked and needed so badly.

The situation that has been outlined is neither necessary nor desirable. In many fields of engineering, for example engineering mechanics, thermodynamics, fluid mechanics, and electronics, much of the technical knowledge taught in universities is very close to the basic sciences on which these fields rest. It is therefore desirable that the faculty members teaching these subjects, even in an elementary way, be thoroughly grounded in the related fundamental science, as well as in the application of this science to engineering problems. Perhaps the breadth of scholarship re-

quired of an engineering professor should be even broader than that of the physicist, certainly it should not be less.

It is also desirable that the ablest and more analytically minded young engineers, who in the future enter these fields of engineering either as workers in industry or as teachers, be thoroughly grounded in the pure science that underlies their engineering interest. This implies that these men should devote more than four years, and usually more than five years, to obtaining their training, and that in the more advanced stages of their training they be brought in contact with inspiring engineering teachers who really know their science as well as their engineering. This does not mean a fifth year added to the undergraduate program in order to crowd in still more undergraduate level work. Neither does it mean three years of relatively undirected research beyond a bachelor's degree. Rather it involves a *coordinated* program of *research* and *organized instruction* at the fifth, sixth and seventh year levels.

It may be felt on the part of some that carrying a substantial number of brighter men to these higher levels is a form of overtraining, in which men are equipped with knowledge that will not be used in most engineering work. I can see no more justification for this viewpoint than to argue that it is undesirable for a high school teacher of mathematics ever to have had analytical geometry and calculus on the grounds that analytical geometry and calculus are not taught ordinarily in high school. I cannot subscribe to the thesis that an engineer will be harmed by having been led to the top of the mountain and shown the whole field of knowledge that relates to his engineering interests.

Experience has shown that after leaving school men relatively seldom, and only with great difficulty, open up higher level fields of knowledge of analytical types that they have not previously been introduced to in school. In contrast, engineering practice is readily picked up on the job, often even without a college education. It therefore behooves us teachers to do everything possible to aid the more promising of our students to open as many doors as possible during the precious years that they are in school. We can never tell behind which door will lie the real opportunity for the individual.

The present time is unusually favorable for developing these higher aspects of engineering education, and for building up the scientific and professional position of the engineer both in academic circles and in industry. There are now a large number of engineering students carrying on graduate work who are adequately financed as a result of G.I. benefits. There is today a large demand for men possessing advanced training, in contrast with the pre-war situation when, for example, one of the very largest units of the electrical industry repeatedly stated that it *preferred* to employ men *without* any *advanced* training—the idea being to catch them young and bring them up in the way of the company. Another extremely favorable factor in the present picture is the large government sponsored research program now being carried on, in which the engineering schools of many universities are participating. As a result of these factors, engineering schools are now in a position to carry on advanced instruction and research at a higher level and

on a larger scale than ever before possible.

The administrative policies of research should be those policies that are necessary to accomplish the objectives discussed above. The important thing in the administration of research is to have clearly defined and worthwhile aims which are never lost sight of. In the final analysis, details such as overhead rates, methods of paying project supervisors, handling of inventions, business procedures, etc., although necessary, are of secondary importance.

In the administration of research we start with the fundamental fact that research is built around men, and that the most effective research programs are usually those carried on by "teams" involving an outstanding leader, often but not necessarily with one or two permanent or semi-permanent associates. The remainder of the team commonly consists of men who are in various stages of training. The research carried on by such a team is characterized by *continuity* involving a *long-range program* devoted to work on *important* and *closely related* problems. Effective basic research is not done by assigning problems to a staff member who happens to be free of commitments at the moment.

Sponsored research such as now available provides an unequalled opportunity for the establishment of effective research teams of the character described above. The financial assistance represented by sponsorship covers the cost of materials, provides the technician assistance required for efficient operation, assists in financing the key members of the team, and provides financial assistance where required by student members of the team.

One of the important values of an effective research team to an educational institution is that it provides a means by which young faculty members of promise can make up for the deficiencies of their original scholastic training. This is done by attaching such men to a team for a period of time, without sacrifice in total income, and under arrangements whereby a substantial fraction of their working time goes into the research and into related studies of the fundamental science pertinent to the research.

There are certain fundamental principles involved in the administration of research which must never be forgotten. First, the key men in any research group or team must be able to work directly on the programs themselves; they are lost to research if they become simply desk administrators of a research program.

Second, research requires leisure to think, *i.e.*, freedom from pressure. No ordinary man, however, brilliant and creative, can do himself justice if he is teaching three courses, must concern himself with the problems of 75 students who look to him as an advisor, and then be expected to put in half time on research. Third, one must not spread out thinly, but rather should concentrate on strength. The desirable plan for a typical department to follow is to build its staff and facilities over a long-range period with an eye to creating strength in only one or two specialties.

Finally, continuing vigilance is required to prevent the research program from degenerating into something else. Many like to play with technical things, particularly when plenty of money is available, but only a few can spearhead a productive research program. It is almost as easy for "research" to degenerate into puttering as it is for

water to run downhill. These dangers can be largely avoided by carrying out research as part of a carefully planned program that is closely directed by leaders of broad background who have already demonstrated a capacity for productive research. Poor results can generally be expected when inexperienced young men, however bright, are assigned to a subject and then turned loose to carry on "research" without the benefit of experienced guidance or example. Such people may deserve an A for effort, but they achieve a C in preparation for life work.

The successful realization of research objectives along the lines outlined will have a number of very important effects on engineering. It will first provide industry and government with a supply of highly trained men who will make a far more valuable contribution to the technological development of the country than these same men would make if limited to a standard four-year undergraduate training, or even a five-year training. It will also provide a pool of men from which universities can obtain staff members having the requisite scientific background and scholarly training required for leaders of new teams to keep the system growing and expanding. Vision and hard work are required on the part of engineering administrators to take full advantage of the present situation, and to use it to raise the engineering profession to a level where one has a true *engineering science* adequate to meet the needs of the country. It will among other things require that those of us in the administrative end of engineering establish standards for the qualifications and achievement for new staff members that are higher than we ourselves could possibly have met with the training, or rather lack of training, that we were able to obtain.

We must also get the best engineers on the university staffs, instead of letting industry have them. This may increase university expenditures for engineering, and it may result in engineering teachers receiving a higher level of remuneration than teachers of subjects that need not attract their men in competition with industry. None of us should be concerned, however, if engineering is able to achieve such a preferred position in an academic organization.

The war presented an opportunity for scientific achievement in engineering which the engineers were not able to take full advantage of. The present postwar era provides an opportunity to retrieve this situation for the future. It is doubtful if there will ever be another equally good chance. The engineering profession should and *must* take full advantage of the present opportunity. It is up to those directing the research activities in engineering schools to take the leadership that will lead to this result. It is in their power to make engineering a science of high degree, or they can let it become merely a vocation.

The Scope of Engineering Research*

By L. W. CHUBB

Director, Westinghouse Research Laboratories

This symposium on engineering research in college and industry should be very helpful in answering many questions regarding the supply, the desirable characteristics, and methods of seeking out and educating research personnel.

There is an ever increasing number of research and development engineers needed in industry. The late war and the general trend for several years has taught us that the life span of marketable products is becoming shorter and that improved devices, materials, and methods of fabrication are constantly demanded to conserve our national resources, off-set increasing labor costs, and supply better things at lower cost to a more discriminating public. This tendency has created sharper competition, and a relatively greater proportion of research, invention, and development activity in the engineering fields.

Industrial research is considered by some as one of our national resources and it is rapidly becoming almost an industry in itself. Back in 1920 there were only approximately 297 companies that maintained industrial research laboratories. The number and size of these laboratories has since then grown continually until today there is almost an eight-fold increase in twenty-six years. Recent figures comparing the magnitude of industrial research and the distribution of technical personnel will be of interest. These figures cover only *research in industry*. They do not include industrial research carried on in research foundations, at the universities, nor do they include government laboratories or the enormous research and development carried out by the Army, the Navy and other governmental institutions.

In industry alone the total number of laboratory personnel is over 133,000. Of this, the professional personnel numbers to about 54,000 and additional non-professional but technical personnel numbers 34,000. The 54,000 professional workers are divided as follows:

Chemists	21,095
Biologists	1,659
Engineers	20,637
Doctors of Medicine	236
Physicists	2,660
Metallurgists	2,364
Psychologists	22
Geologists	81
Other scientific professions (unclassified)	5,567

It will be noted that chemists and engineers stand out far in advance and I believe it might be said that over 90 per cent of all research in industry is really engineering research, or directed toward engineering application. In comparing these figures of the National Research Council with similar figures for 1940, we find an increase of approx-

* Presented at the December, 1946 meeting, Middle Atlantic Section, A.S.E.E.

imately 90 per cent in total personnel and an increase of about 45 per cent in professional personnel.

The addition of research foundation activities, regional laboratories, commercial laboratories and government research, all of which are relatively new, would swell these figures enormously and make a grand total of research activity several times that carried on just prior to the war.

A word regarding the Army and Navy research seems pertinent in this discussion as their extensive programs must draw technical personnel from the men trained in the colleges. The government fiscal program for research and development of all kinds is $1,613,000,000. Eighty-four per cent of this is for the Army and Navy. The Navy part is required for the Bureau of Ships, the Bureau of Ordnance, the Bureau of Aeronautics and the Office of Naval Research, formerly known as the Office of Research and Invention. The *operating bureaus* spend their funds mostly on engineering development of weapons, apparatus and structures of all kinds for Naval use. The O.N.R., on the other hand, contracts for research of a more or less fundamental or basic nature which may give useful information for future application. Certainly this will result in a great deal of new knowledge and incidentally train many research workers.

The activities of O.N.R. started with an appropriation of $20,000,000, now raised to $45,000,000 and distributed roughly as follows: eleven million to naval laboratories, only seven million to industrial laboratories, and twenty-six million to university and college research. Forty per cent of this total is earmarked for nuclear physics, fourteen per cent for electronics, and the rest, forty-six per cent, for guided missiles, physics, chemistry, mathematics, and medicine. The total Navy program will require approximately eighty-one thousand research workers.

There is no corresponding Army agency like the O.N.R. Their research is to be carried out as specific tasks administered by the technical service commands and the Manhattan District.

For both services, a four-man board consisting of Dr. Bush, formerly Director of O.S.R.D., Dr. Condon, Director of the National Bureau of Standards, Admiral Lee representing the Navy, and General Aurand representing the Army, will coordinate the activities and decide which get priorities of equipment and trained men. It has been estimated that 45 per cent of all graduates coming from the colleges will be required for this work while government research and development continues at the contemplated level. Despite the present scarcity of graduate engineers, the program provides no direct action to locate and spur the training of scientists and engineers.

With all this increase in research, the addition of new research foundations, commercial laboratories and expansions in industry, the colleges are going to have a much greater demand for furnishing engineers suitable for research and development.

Engineering research which we are discussing today might be limited to that in the physical sciences directed toward engineering application in the industries, particularly in the electrical, mechanical, civil, and chemical fields. I might add that most of the national industrial effort is for engineering application.

We in industry classify scientific research as:

(1) Fundamental research which is carried on for the sake of obtaining new knowledge without having any specific application in mind. This prospecting, which we try to keep at a level between twenty and thirty per cent of the total, is done in fields which we believe most liable to give valuable knowledge for *future* application.

(2) Basic research involving the same theoretical and experimental methods, but for the purpose of obtaining scientific data for application.

(3) Practical or specific research done to solve some problem, trouble, or engineering limitation of materials, process, or cost reduction which is of value for a particular application.

The third type of research might be classed as engineering development and is carried on cooperatively with the engineering departments who have the responsibility of the complete development of new products or new lines of products. There is no sharp dividing line between engineering research and development. We think of development as work usually carried on by experimental and test methods to obtain information for direct application. This may be done in the research laboratories where unusual equipment and men of special training are available, or in the engineering laboratories where there is engineering skill. Engineering development generally involves more than technical data. It involves design, competitive considerations, compromises in materials, dimensions, ratings, tooling, etc. This puts great responsibility on a development engineer, for he must exercise the best possible judgment in meeting commercial requirements, costs, and performance specifications, sticking closely to standards, but not necessarily to the optimum design for each individual product. To meet this responsibility, the development engineer needs research information in ever increasing quantity.

In the larger industrial companies, research is usually set aside from the various engineering departments, responsible for design and development of the product. However, very close cooperation is maintained between the laboratories, engineering and production departments.

The centralization of research precludes the necessity of duplicating unusual facilities and specialists in the various fields of science and engineering. Centralization also has the advantage of providing a clearing house and source for the dissemination of new knowledge. Data obtained for or in one engineering department may find multiple application in other plants.

Research and technology is becoming so complicated and extensive that it is following the same pattern as the family economy. We no longer depend upon the genius to invent, develop and make, for the market, products which involve work in several fields of science and engineering, any more than we depend upon the family unit to be self-supporting by making their own shoes, clothes, supplies, or raising their own food for sustenance. Teamwork of specialists all adding their part to an ambitious undertaking is the only practical method of meeting the modern call for new advances in technology. The industrialist *must* provide facilities and depend upon cooperative contributions of men trained in research, engineering, and production.

Now in addition to the cooperation of men trained in different fields, there must also be good cooperation of men having different characteristics, but trained in the same field or branch of engineering.

A research or development engineer should be imaginative, a critical observer, dissatisfied with things as they are. He should be a creative thinker, inventive, have good technical ability, good judgment, preferably an aggressive individual with lots of initiative.

The men you educate need not necessarily possess all of the foregoing attributes to a high degree, for they can be useful in research when teamed with others having the supplementary characteristics.

There are certain qualities, however, which must be possessed by all research workers. They are, in order of importance: cooperativeness (ability to get along well with fellow workers), honesty, patience, and a good fundamental training in the physical sciences and engineering branch pertinent to their chosen activity.

Frequently a good team for a project will consist of the creative thinker, or inventor, who may be a poor experimenter or planner, an aggressive worker who likes to carry through the ideas of others, and perhaps other teammates who supply additional functions needed to bring a project to an early and successful conclusion.

This method of using men brings up a question of individual training. Should they be educated to play any position on the team, by endeavoring to reduce their deficiencies, or should they be developed for higher proficiency along lines in which they show a natural aptitude?

These are questions best answered after graduation. In college, we believe emphasis should be placed on fundamental courses. Specialization and development of natural aptitudes will come with experience after employment in industry and the correction of deficient personal characteristics will often come through the teamwork with others.

Engineering Principles in Biophysics

By KARLEM RIESS

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Biophysics is that branch of applied physics which utilizes the principles and techniques of physics for the investigation of biological and medical problems. This is accomplished through the application of facts and tools of engineering, chemistry and medicine. Modern biophysics includes such topics as the study of the physics of living organisms, the utilization and application of X-rays, radioactivity, ultraviolet and infrared light, spectroscopy, surface phenomena, membrane studies, problems of nerve conduction, the application of physics to body mechanisms, and the use of research aids such as the ultra-centrifuge, the electron microscope and the mass spectrograph. While these may seem to be unrelated subjects, all are linked to the general theme—the explanation of a biological effect by means of a physical principle. In each of the subdivisions mentioned above, we find applications of basic engineering principles and materials. Some of these will be discussed in this paper.

The generation and use of X-rays is as familiar to engineers as to physicists. Widespread applications of X-rays in routine medical diagnosis, in X-ray diffraction and in many industrial installations have taken place in the past few years. The biophysicist uses X-rays for radiation therapy and to produce changes by irradiation. Studies of the nature of chromosomes and of mutations have been of great value in our efforts to understand the living plant and animal cell. The engineer uses a portable X-ray unit for metallographic inspection, and follows safety requirements set up by the biophysicist. The measurement of transmitted radiation through various thicknesses of lead resulted in the manufacture of protective gloves, gauntlets and aprons of rubber impregnated with lead oxide. These serve as adequate protection for most of the smaller installations. Concrete is also used as a protective material. A concrete barrier of thickness 26.5 cm. will shield the operator from 400 kilovolt radiation.

If the operator of an X-ray unit is subjected to irradiation, the safe or tolerance X-radiation dosages have been established. The biophysicist has found that the body cells which are most sensitive to X-radiation are those of the reproductive organs, bone, muscle and skin. Brain and nerve cells are among the most resistant.

Biophysical studies of X-rays have led to the extensive development of fluorescent screens. These are accepted as fundamental components of engineering apparatus, such as the cathode ray oscillograph.

The methods of the chemist and chemical engineer are combined in the field of applied radioactivity. The

quantity production of radium salts from natural ores requires many of their industrial techniques. The extraction and purification of radon gas in semi-automatic stills is another example. The biophysicist then uses the end products, the radium and the radon, for tissue irradiation, for the bleaching of butter, for investigation of necrosis conditions, and to study the rate of cell growth and repair.

The cyclotron, betatron and synchrotron are engineering as well as physical achievements. The older and more familiar cyclotron whirls positive ions in ever increasing circular paths between the poles of a magnet. The ions are thus given an increasingly high velocity and may be used for the bombardment of materials. A source of high energy projectiles is thus available for the transmutation of chemical elements. Many of the nuclei after transmutation are artificially radioactive. These are the tracers for many biological experiments.

The betatron is an electron accelerator, often called a glorified doughnut. Electrons are rotated in a circular path, acquire high energy, and when they strike metal targets produce X-rays corresponding to one million volts.

The synchrotron is the newest and most compact type of electron accelerator. The electrons are speeded up as the magnetic field increases, and, in the presence of an oscillating electric field, revolve in groups. The electrons may be directed against a target and X-rays produced. The commercial units produce seventy million volt X-rays, and units up to three hundred million volts are under construction. The advantages of this accelerator over the betatron is its small size and low weight. The commercial development of these three accelerators would have been impossible without the engineer.

The radioactive tracers produced by the cyclotron, and also by the atomic pile procedures, are extremely valuable in biophysics. Examples are the use of carbon-14 in metabolism studies, of sodium-24 in fluid circulation in plants, of phosphorus-32 in bone studies, of iodine-128 in the study of thyroid deficiencies, of thorium B-212 in the estimation of blood volume, and the many experiments, as yet inconclusive, on the use of tracers in the study of cancer. The petroleum engineer uses radioactive materials to map oil pools. The metallurgist uses tagged phosphorus compounds to trace phosphorus in steel refining. Heavy hydrogen or deuterium atoms are used in cracking processes and in the hydrogenation of oils. All of these and hundreds of others would have been impossible without the engineering techniques which enter into their manufacture.

The illuminating engineer has developed many new types of commercial and home lamps. The biophysicist is interested in all of these, particularly the mercury vapor lamps, the many varieties of sunlamps and the sterilamps. The effect of ultraviolet radiation on the skin has been extensively studied. It has been found that the tanning of skin is a photodynamic action in the presence of oxygen, and is largely due to the oxidation of pigments in the skin in a reduced, colorless state. These pigments include melanin, melanoid and carotin, commonly found in carrots.

The bactericidal action of the sterilamps is due to ultraviolet radiation principally in the 2537 Angstrom region. The transportation of pathogenic bacteria through air to a wound has been greatly reduced by sterilization

of air in operating rooms. Sterilization of water with ultraviolet has been found feasible only if the water is treated in layers less than 2 cm. thick and if the flow is moderate.

Use of ultraviolet sources for irradiation of edible materials is of increasing industrial importance. The sterols become antirachitic on irradiation. The absorption of ergosterol disappears with irradiation, but activation yielding vitamin-D results.

The commercial photronic or barrier-layer photoelectric cell finds application in many biophysical instruments. For example, the Kuder colorimeter measures calcium or phosphorus in blood, albumin in urine, hemoglobin, sugar in blood or urine, and urea nitrogen.

One of the most interesting fields of biophysics is that of nerve conduction. A nerve is composed of many separate fibers. Each fiber is comparable to a well insulated wire, with the insulation squeezed in at regular intervals for some, and removed completely for others. The insulation corresponds to the medullary sheath of myelin and the bare wire to the axon of the nerve. These fibers vary in length. There is a difference of potential across the surface of the living fiber. This, curiously, disappears when the nerve is deprived of oxygen. The axon of the stellar nerve of the giant Atlantic squid has been used in many experiments.

A nerve fiber is equivalent to a resistance-inductance-capacitance series circuit, with applied direct electromotive force. Differential equations for the propagation of current along the axon have been set up and solutions obtained. The longitudinal and transverse impedance of the axon during stimulation was measured using a Wheatstone bridge with amplifier and cathode ray oscillograph over a range from 30 cycles to 200 kilocycles per second. There is associated with the nerve fiber a monophasic action potential. This is a wave of activity along the nerve following a stimulus and is a negative pulse of maximum five millivolts. There is also a change in membrane potential during current flow. The membranes display both inductive and capacitative reactance, while the axoplasm and connective tissues function as resistances. The passage of a stimulating impulse along a nerve fiber may be detected with silver-silver chloride-sodium chloride nonpolarizable electrodes in contact with the surfaces of the nerve. In the myelinated fibers the impulse speed may be as high as one hundred meters per second; in the unmyelinated, as low as one meter per second.

Nerves of the squid are not the only cells used in these experiments. Cells of the plant *Nitella* give the same results. There are also action potentials and excitation conduction in smooth-muscle fibers. The smooth muscles of the visceral organs show a brief action potential on contraction. Smooth muscle activity is thought to be due to the discharge of impulses by action potentials.

In many plants and trees there are inherent electromotive forces. For example, in Douglas fir trees an electromotive force is set up between one electrode in the center xylem tissue and one at any point on the outer surface. Such data are being used to study the upward and downward conduction of sap in the xylem and phloem cells of the plant.

A fundamental law in mechanics is Newton's second law of motion. The mathematical formulation of this law

in terms of the time derivative of velocity is well known. An analogous relation may be set up between the time derivative of an excitation and an applied stimulus. All of the procedures of theoretical mechanics may then be followed for the excitation equation. Unfortunately the experimental stimulation of nerve fibers with alternating currents does not exactly follow the desired theoretical results.

Electronic devices are of great importance in biophysics. Mention has been made of the cathode ray oscillograph as a detecting device. Various types of amplifiers, oscillators and control units find wide application. In the building of a mass spectrograph for the identification of isotopes the control unit is composed of several types of amplifiers. Amplifiers and oscillographs are used with Geiger counters. The electroencephalograph for the study of brain pulses and brain patterns uses two amplifiers, several filter circuits and a mechanically recording oscillograph.

A familiar illustration in mechanics is that of the coupled oscillator, which may be pictured as two identical pendulums coupled together by a spring. Two of the small bones of the middle ear, the malleus and the incus, function as a coupled oscillator. Vibrations impressed on the malleus are transmitted to the end of the incus exactly as energy is transferred from one of the coupled pendulums to the other.

All of the fundamentals of acoustical engineering are utilized in auditory biophysics. The decibel scale of measure, loudness measurements, noise meters, pitch, and hearing thresholds have been studied from the point of view of the physics and physiology of the ear. Measurements of aural harmonics have been made by observing the fluctuating electrical potential set up in the cochlea of the inner ear by pressure disturbances which cause the eardrum to impress motion on the cochlear fluid and thus generate the potential. The frequencies are measured by means of a vacuum tube wave analyzer.

Related to this is the hydrodynamic theory which treats the cochlea of the ear as a hydraulic tunnel with an elastic wall, a selective response mechanism and a large damping factor. In engineering terms this would follow the analysis of a hydraulic system contained in a cylindrical vessel, with elastic walls and a pressure disturbance propagated along the walls. The mathematical analogy here is quite satisfactory.

Mention should be made of the microscope and the electron microscope as valuable tools in biophysics. The engineering principles in the electron microscope are numerous and familiar. The electron microscope is finding wide application in the study of virus diseases, identification of viruses, and in the study of the mechanism of cell division.

There have been studies with ultrasonic vibrations for depolymerization of starch and gelatin. These vibrations have been used to break down the protein hemocyanin obtained from the edible snail *Helix pomatia.*

These rambling examples are but a few of the many possible applications of engineering principles and techniques to biophysics. The coming years will bring the engineer, the physicist and the biologist closer together for the solution of mutually interesting problems in the border field of applied biophysics.

The Naval Reserve Officers Training Corps Program in the Engineering Colleges

By J. H. BELKNAP

Chairman, Division of Engineering, University of Rochester

The Holloway Plan as authorized by Public Law 729 has established NROTC units in 52 colleges and universities. The training offered in these units is designed to provide "a steady supply of well-educated junior officers for the line and staff corps of the Regular Navy and to build up a reserve of trained officers who will be ready to serve their country at a moment's notice in a national emergency." The plan supplements, in point of numbers, the program offered by the Naval Academy.

The arrangement provides for commissioning and granting of baccalaureate degrees to those who satisfy the requirements set up by the Navy and the colleges.

This paper has to do with the integration of the regular and Naval programs in the engineering colleges and is based upon a survey just completed. It is inspired by the problem which is brought to the engineering colleges by the addition of 24 Naval Science course credits to an already crowded engineering curricula. The study deals only with undergraduate curricula in engineering as offered by the concerned colleges.

In the preparation of this paper full use has been made of the information in the hands of the Association of 52 Colleges offering the NROTC programs. Dr. Alan Valentine, president of the Association, has indicated his interest in the study. Data obtained through the use of the questionnaire of May, 1947 will be made available to the Association for their analysis with respect to the combination of Navy courses and engineering curricula.

Thirty-four questionnaires have been completed and returned. The students involved total 3,310 of which number 1,585 or 48 per cent are following engineering curricula.

It is known that of the 34 colleges replying, 32 offer the B.S. in particular engineering fields at the end of 4 years of successful undergraduate preparation. Two are following the 5 year plan.

Of the 32 colleges offering the B.S. degree in 4 years, 19 will provide both degree and commission in 4 years; and of the entire group, 17 will require additional time up to 10 semesters or 5 academic years for both. Six colleges offer the Bachelor of Naval Science Degree, or the B.S. without designation, and commissions at the end of four years and will require additional time for the engineering degree.

The great majority of the institutions interrogated offer full 24 credits for the Naval Science courses. Space is

made available for the additional 24 credits in Naval Science by the omission of courses in the humanities and social sciences and courses in engineering electives. In no institution replying is it known that Naval Science courses are substituted for the physical sciences and mathematics. In only one or two instances are "regular" courses in engineering set aside to make room for the Naval Science courses, and in those cases it is understood that all essential courses have been retained.

Of the 19 colleges offering both the B.S. degree and commission in 4 years, 16 are satisfied with the arrangement. Of the full group of those who indicate lack of satisfaction with the plan as now used, only 7 propose that betterment would be achieved if the plan were to be extended. Of the total group of the 34 colleges, 9 propose that the combination courses in engineering and Naval Science be extended to 10 semesters (5 academic years) and one proposes 9 semesters and a summer session. An additional 8 suggest some extension but do not indicate how long the extension should be. Accordingly 18 out of the 34 favor a lengthening of the combination program beyond 8 semesters or 4 academic years. This, to repeat, is in contrast with the 16 colleges in which there is satisfaction with the 4 year plan.

Some of the answers indicate "satisfaction" with the 4 year plan and yet propose an extension beyond 4 years! From this and several other observed disagreements it may be understood that the problems are not yet happily resolved and that changes may be viewed with favor.

To summarize certain of the findings, it is apparent that all who answered the questionnaire analyzed their curricula in terms of the following breakdown:

SAMPLE COMPARISON

TYPICAL MECHANICAL ENGINEERING CURRICULUM

ECPD Basis (Cr. Hr.)	Subjects	Regular (Cr. Hrs.)	NROTC (Cr. Hrs.)	Courses Dropped
		REGULAR	NROTC	
40.4	Mechanical Engineering	38	30	6—Eng. Elect. 2—Surveying
20.6	Other Engineering	16	16	None
10.9	Mech. and Hydraulics	14	14	None
5.9	Graphics	8	6	2-Shop Drawing
2.9	Shop	3	2	1-Foundry Lec.
15.6	Physical Sciences	16	16	None
18.9	Mathematics	14	14	None
15.1	Arts (Humanistic-Social)	24	24	None
4.2	Phys. Training	4	4	None
5.5	Non-Engr. Electives	6	0	6—all as selected
0.0	Naval Science Courses	0	18*	Added
		143	144	

* Eighteen rather than 24 N.S. credits required because Navy agreed to waive N.S. 401 and N.S. 402.

A STUDY OF THE NAVAL RESERVE OFFICER TRAINING

No.	(1) NROTC Students in Unit			(2) Time Required for "Regular" B.S. Degree in Engr. Field		(3) Credits Authorized for N.S. Courses	(4) Credit Hours Dropped to Provide for N.S. Courses			(5) Naval Science Courses Waived by Navy
	Engr.	Arts and Other	Total	4 years	5 years		Humanistic	Reg. Engr.	Engr. Elect.	
1	35	19	54	x		24 (in equiv. qtr. crs.)	18 qtr. crs.	0	12 qtr. crs.	None now, but anticipated
2	103	49	152	x		18 in Engr. 20 in Arts	12	0	6	None
3	50	50	100	x B.S. in N.S.		24				None
4	61	32	93		x	24 (not all depts.)	0	0	0	
5	66	95	161	x		24	22	0	0	N.S. 402 (modified to 1 sem. course)
6	167	0	167	x		30 qtr.				None
7	13	95	108	x		24				N.S. 401 and 402 (?)
8	81	4	85	x		24	9	9	6	None
9	65	87	152	x		24 for some			?	None
10	70	23	93	x		24			16/18	?
11	27	27	54		x	33 qtr. c.	15		15/3	N.S. 411 and 412 (on recommendations)
12	95	87	182	x		24	6	0	6	Next year?
13	25	16	41	x		24				None now, but anticipated
14	5	21	26	x		24				None
15	10	31	41	x		24				None
16	14	31	45	x		24				None
17	38	103	141	x		24	27 qtr. hr.	9 qtr. hr.		None
18	29	42	71	x		24	12	6	6	None
19	22	31	53	x		24	3 qtr. hr.	3 qtr. hr.	30 qtr. hr.	None
20	40	45	85	x		24	?		?	None
21	43	178	221	x		24	15	0	3	N.S. 401 and N.S. 402
22	?	?	?	x		24	6	0	6	None
23	101	5	106	x		24	6	0	3	N.S. 401 and Part N.S. 402
24	21	10	31	x		21	?	?	?	N.S. 401
25	55	43	98	x		24	6 (?)	5	6	N.S. 401 and N.S. 402
26	37	43	80	x		24	?	?	?	None
27	49	30	79	x		24	6	8	10	None
28	11	85	96	x		24	?	?	?	None
29	46	61	107	x		12 hrs.	?	?	?	None
30	32	54	86	x		24	?	?	?	None
31	11	12	23	x		24	?	?	?	N.S. 213, 411, 412
32	38	53	91	x		?	?	?	?	None
33	65	60	125	x		12	?	?	?	None
34	60	203	263	x		24	?	?	?	None
	1585		3310							

(a) Physical sciences and mathematics.
(b) Required engineering subjects.
(c) Humanistic and social studies.
(d) Engineering electives.

It is definitely established that the first two groups may not be reduced but that there is some flexibility in the last two. All colleges reporting on present and contemplated operations based upon a plan for graduating and commissioning within a four year period have made adjustments with the (c) humanistic and social studies group and the (d) engineering elective group. By and large the subjects listed within all engineering curricula quite uni-

COURSES IN 34 COLLEGES AND UNIVERSITIES

No.	(6) Time Required to Obtain both Degree and Commission		(7) Is Present Arrangement Satisfactory?		(8) Courses which Substitute for Those Waived by Navy (See column 5)	(9) Recommendations to Extend		(10) Proposals
	4 years	5 years	Yes	No		Yes	No	
1	x			x		x		Extend
2	x			x		x		Ex. to 9 or 10 Semesters
3	B.S. in N.S.	Both		x			x	
4		x	x		H.P. and E.E.		x	
5	x		?				x	Provisional Arrangement
6	x		x					
7	x			?	Approp. E.E. and/ or Steam Courses		x	
8	x		x				x	
9	B.S. in N.S.	Both	x			x		Ex. to 10 Sem.
10	x		x					
11		x	x		Humanistic and Elect. Engr. Courses		x	
12		14 qtr. 9 sem.+ Sum.Session		x		x		Ex. to 9 Sem. and Summer Session
13		4+2 qtrs.		x		x		Ex. to 10 Sem.
14		4+Sum. S.	x			x		Ex. to 10 Sem.
15		x	x			x		Ex. to 10 Sem.
16		x	x	?		x		Ex. to 10 Sem.
17	x		x				x	
18	x		x?			x		Ex. to 10 Sem.
19	x		x				x	
20	x		x			x		Ex. to 10 Sem.
21	x		x		Seminar to cover ship const. and damage control		x	
22	x		x			x		Extend
23	x		x		Any equiv. H.P.		x	
24	AB	B.S.		x	Crs. in M.E., Ch.E., etc.	x		Extend
25	x(?)		x		H.P. and other approp.		x	
26	B.S. in En.	B.S.	x			x		Extend
27	x		?			x		Change needed
28	B.S.	Both		x		x		Extend
29	x or 9 Sem.		x				x?	Ex. to 10 Sem.
30	x (with overload)		x					Extend
31		Both		x	E.E. Courses	x		Extend
32		Both	x			x		Extend
33	B.S. in N.S.	Both	x				x	Extend
34	x B. of Engr.		x				x	

formly aggregate 140 semester hours for graduation with the baccalaureate degree.

In reading the notes found on the questionnaires and the letters transmitting the questionnaires I have found opinions varying from the one extreme of holding quite inflexibly to a rigid requirement within all engineering curricula to the other which says in effect "we can still hold to sufficiently rigorous requirements and provide both degree and commission in 4 years." A fine indication of patriotic interest has been shown in the replies to the questionnaire.

Some of the colleges report that they have given certain of their required

courses a "Navy Slant" and that the Navy in return has granted that such courses may substitute for the comparable Naval Science courses. An example of such economies is that of the substitution of heat power and electrical engineering courses for the more advanced Naval Science courses. In these cases the reasons for the substitutions are apparent, but in other course comparisons it is not so easy to see the similarities. Possibly the Navy will be able to make adjustments toward the "standard" courses and the Colleges will be able to give their regular courses a "Navy flavor" through the use of examples taken from Marine practice, thus working toward a more nearly common requirement.

By the same token the colleges might well recognize the benefits to be had through the taking of N.S. courses. If, for example, 9 credit hours in the humanistic and social studies and 9 credit hours in engineering electives are set aside to provide for 18 Naval Science course credits, not all is lost! Specifically, an E.E. student might be required to drop 3 credit hours of engineering elective in plane surveying so as to be able to adjust his schedule to include the required N.S. courses. As a compensation for that loss there would be comparable information in the Naval Science courses in navigation and fire control (gun pointing) and in certain respects he would find a more exact use of engineering principles in the Navy courses.

The Navy is in need of college trained engineers and our institutions should assist in every way possible in providing for that need. It is a privilege for the colleges to serve our Nation through the Navy, and our obligation with respect to national defense should not be minimized. The colleges consider it an honor to be selected to aid in the training of those who are to serve in peace and who may be called upon to defend our country in time of war.

The Army and Navy know the importance of engineering education. Without our engineers and their place of work — the country's industries — the war could not have been brought to its successful end. How close was the race is known to many of us. The world knows and acknowledges the importance of engineering education and its product, our young engineering graduates, and the Army and Navy must have their share of the output of the engineering colleges. Therefore our efforts to integrate the needs of industry with the requirements of the armed forces must be effective.

It is significant that we have gotten under way in this important cooperative action involving the Navy and the Colleges, on the basis of the integration of established plans, and with the least amount of disruption of the accepted standards of engineering education. It is evident that we recognize fully the seriousness of the recent world conflict, the need for preparedness, and the continuing threat to world peace. The spirit of give and take has been shown and with the attitudes found in both the Colleges and the Navy the problems remaining will indeed be resolved with satisfactory results.

We should not permit our engineering programs to be reduced in their essential content, and the humanistic and social studies should be retained insofar as is possible. But it is to be recommended that we realistically view the need that our nation maintain its military strength, not for the purpose of waging war, but, through actual military superiority, to prevent war. The

Naval Science courses of engineering type are broadening and also provide an insight into another use of engineering principles. It is right that the Naval Science courses be given full credit and it is fair, too, that they be acknowledged as the equivalent of certain of the more general courses.

It is proposed finally that the Navy, as in this instance, be acquainted with our problems and our determination to serve the armed forces and that the Navy consider the possibility of modifying its in-residence courses to the point that more substitutions may be made. Such changes may necessitate covering more subjects while the students are on cruise. The colleges also should attempt to put in their regular engineering courses, where possible, material of particular interest and use to the Navy. The colleges' obligation should be that of providing the best possible arrangements such that graduation and commissioning may be accomplished in four years, or the shortest possible extension of time beyond four years. The final alternative is to go to a five year plan and hold to all present requirements.

Correlation of Mathematics and Electrical Engineering*

Part I

By H. K. JUSTICE

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Correlation, in the sense in which we are here interested, is a difficult term to define. Whether it should include the mere arrangement of courses in logical sequence is open to question. Some of you may regard the essential requirement of basing each course on carefully planned prerequisites as too fundamental to be classified specifically as correlation. Nevertheless, some reference to the sequence of courses seems inevitable in any discussion of correlation. There should be no need, however, to dwell on this aspect of the subject. All of us know that any curriculum, once established, demands a rather inflexible arrangement of courses.

What I shall have to say will deal with basic courses of the first two years of electrical engineering at the University of Cincinnati. Professor Restemeyer will then develop the subject of correlation in more advanced courses. Professor Restemeyer and I do not in any sense wish to display the Cincinnati plan before you as a model. On the contrary, we present it humbly for whatever merits it may have, in the hope of soliciting frank and constructive criticism.

In the year 1920 the functions, personnel, and scope of the department of mathematics at Cincinnati were greatly expanded. At that time all basic courses of the first two years in statics, dynamics, drawing, and descriptive geometry were placed under the jurisdiction of the mathematics department, as also were courses of the upper years in technical mechanics, strength of materials, indeterminate structures, and (later) vibration problems. The chief purpose of this reorganization was to effect a comprehensive correlation of these subjects with mathematics and with each other. Throughout the period of more than twenty-five years, during which this plan remained in effect, constant attention has been given to the question of correlation. For reasons which I shall presently discuss, a separate department of engineering drawing has recently been established and, for the most part, members of the mathematics department no longer teach drawing.

Our freshman curriculum for all engineering students includes algebra, trigonometry, analytic geometry, statics, descriptive geometry, drawing, and

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vector algebra. Vector algebra, which is offered during the third and final term of the year, includes studies of the scalar and vector products and the scalar triple product, with applications to statics and to space analytic geometry of the point, line, and plane. All these subjects have been handled by the department of mathematics. The freshman program includes also general inorganic chemistry, English, metallurgy, and coordination. To accomplish as high a degree of correlation as possible among those subjects handled by the department of mathematics, proper course sequences are maintained, assignment schedules are carefully prepared in mimeographed form, and all instructors are required to follow the same schedule of topics in each course.

Technical courses of the first two terms of the sophomore year in electrical engineering are as follows: calculus, dynamics, physics, engineering materials, engineering drawing, coordination, and English. At the beginning of the third term all sophomores are turned over to the department of electrical engineering for the following courses: graphical applications of mathematics, electric and magnetic fields, applied kinematics, kinematic drawing, elements of circuit analysis, and elementary electrical laboratory. The last-mentioned course includes the study of direct and alternating current metering, direct current bridge circuits, single phase circuits, and flux measurement. Calculus and physics are continued through this term.

The following outline reflects the correlation which has been accomplished at Cincinnati among freshman courses and courses of the first two terms of the sophomore year in electrical engineering.

FRESHMAN YEAR

I. *Correlation of Drawing with Statics, Descriptive Geometry, Algebra, Analytic Geometry, and Vector Algebra.*

Problems involving the following topics are worked in the drawing room. Different data are assigned to the various students.

1. Resultant of concurrent, coplanar forces by use of the force polygon.
2. Resultant of nonconcurrent, coplanar forces by use of the funicular polygon.
3. Resultant of concurrent, noncoplanar forces by projection on perpendicular planes of reference and subsequent true-length determination of resultant by descriptive geometry.
4. Resultant of parallel forces in space by use of the equilibrium polygon applied to two views. Determination of centroids of areas by similar means.
5. Elementary equilibrium problems by use of the force polygon.
6. Equilibrium of coplanar, nonconcurrent forces by use of equilibrium polygon.
7. Reactions in the three-hinged arch by superposition of effects caused by forces on the separate parts of the arch.
8. Stresses in framed structures by the use of the Maxwell Diagram.
9. Three-dimensional, concurrent forces in equilibrium. The tripod problem and others requiring revolution or auxiliary projection for true-length.
10. Pin reactions in various structures with bending members.

11. Point of intersection of three planes represented by given cartesian equations. Algebraic check.
12. Perpendicular distance from a plane to a point from data in cartesian form. Analytical check by vector methods.
13. Perpendicular distance between two nonintersecting lines from data in cartesian form. Analytical check by vector methods.

II. *Correlation of Vector Algebra with Analytic Geometry and Statics.*

1. While the course in vector algebra is intended primarily to furnish the background for vectorial mechanics and electrical engineering courses, correlations are established with analytic geometry and statics in problems of the following types:

a. Point of division.
b. Standard problems in space analytic geometry of the point, line, and plane, such as were mentioned above under I.
c. Moment of a force about a point and its use in determining the moment about an axis.

SOPHOMORE YEAR—ELECTRICAL ENGINEERING

I. *Correlation of Calculus, Dynamics, and Physics.*

1. Calculus and dynamics are handled by the department of mathematics and are taught concurrently with physics.
2. Each instructor has the same students in both calculus and dynamics. The theory of dynamics is taught from the vector standpoint.
3. Integration is introduced early in the calculus course to provide a tool for mechanics and physics. This makes possible the inclusion of a great variety of motion problems in kinematics, as for example the projectile problem from the standpoint of integrating acceleration components.
4. Harmonic motion (from both the kinematic and kinetic points of view) is treated in dynamics and omitted from calculus.
5. Related rate problems are studied in calculus and are concurrently treated in dynamics from the standpoint of velocity components, relative velocity, or instantaneous center, and the various solutions are compared. A typical elementary example is that of finding the speed of the upper end of a ladder whose base is moved at a specified rate.
6. Because statics and dynamics are offered as separate courses in the first and second years, respectively, relatively little time is devoted to these topics in physics. The time thus saved in the physics course is devoted largely to electricity and magnetism.
7. Hyperbolic functions are covered rather thoroughly in the calculus course and their relation to trigonometric functions is emphasized.

II. *Correlation of Sophomore Drawing with Mathematics and Electrical Engineering*

1. The first term of sophomore drawing includes technical sketching and assembly drawing of electrical equipment. Air-gap variable condensers of the Johnson type are used as models.
2. The second term of sophomore drawing includes a study of empirical equations by the method of averages and the method of

least squares. In order that the student may gain familiarity with electrical terminology and phenomena exclusive used is made of experimental electrical data.

3. The third term of sophomore drawing (called graphical applications of mathematics) deals with scales and scale moduli, alignment charts, and graphical differentiation and integration.

I should be remiss if I failed to inject a word of warning on the danger of carrying correlation too far. Some of you may already have detected shortcomings in the program which I have outlined. The principal fault as we see it lies in freshman drawing. In our eagerness during past years to incorporate in drawing a high degree of correlation with other courses of the freshman year, some of the essentials of pure mechanical drawing were sacrificed in favor of graphical problems involving algebra, analytic geometry, statics, and vector analysis. As a result of this practice, it was found that students who were placed on co-op jobs in drafting rooms were found to be deficient in some of the mechanical aspects of drawing. Steps have recently been taken to remedy this situation. The remedy, of course, consisted in restoring those essentials of drawing which had previously been deleted.

Another difficulty which has been recognized at Cincinnati is of an administrative nature. I have indicated that engineering drawing was formerly under the jurisdiction of the department of mathematics and that recently a separate department of drawing has been created. The principal reason for this change is that under the original plan of requiring members of the mathematics department to teach both mathematics and drawing, considerable difficulty was experienced in locating men who were fully qualified in both fields and who were also willing to teach drawing. The obvious answer to this was to create a separate department of drawing. Fortunately, the head of the new department is one of our experienced teachers in mathematics whose inclination is still to preserve all the correlation possible between drawing and other subjects.

Before closing I should like to say a word in favor of a problem course, preferably in the sophomore year with calculus as a corequisite, in which the student is called upon to solve assorted problems from the various fields of engineering and science. About ten years ago I had occasion to develop such a course for a group of sophomores in general engineering, and to teach it for several years prior to the recent war. The results convinced me of the importance of a course of this kind in developing the skill of the student, in demonstrating the utility of mathematics as a scientific tool, and in furnishing an excellent means of correlating the subject with various branches, or with some particular branch, of engineering. In this connection your attention is called to a relatively recent book entitled "Engineering Problems Illustrating Mathematics," which has been sponsored by the Mathematics Division of A.S.E.E. and was prepared by a committee from this division under the chairmanship of Professor John W. Cell. The book contains a large number of problems, many of them from electrical engineering, and seems to be well suited for a problem course in which mathematics through calculus is correlated with engineering.

I wish also to emphasize the need for close liaison between departments in the teaching of engineering and science subjects. Especially is this necessary where two courses are being taught concurrently by separate departments and one of the courses is dependent on the other, as in the case of physics and calculus, calculus and dynamics, or dynamics and physics. Pains should be taken to arrange both courses in such a way that each assignment is based exclusively on material previously covered.

Not only does the careful correlation of courses exhibit the interrelationships of various fields of science and engineering, thereby increasing student interest, but also it affords the opportunity of reiterating basic concepts. It is a well-known pedagogical principle that a student learns by repetition. Let us offer him the best means to his learning.

Part II

By WILLIAM E. RESTEMEYER

University of Cincinnati

An electrical engineering student when asked about his technical courses replied that they contained many different topics, all of them mathematics in one form or another. Of course what he meant by this remark was that the fundamental laws of electrical science are expressed in mathematical language because they involve relations between the measures of physical quantities. It therefore becomes necessary for those interested in science to be able to understand this language and to use it.

It is the combination of scientific experience and familiarity with the techniques and results of mathematics which has produced the technological wonders of our present day world. The past ten years has brought about a tremendous increase in the scope of electrical engineering and thereby a strong need for revisions in electrical engineering education programs. Noteworthy examples of this trend may be found as early as 1942 in the paper of Professor Bewley[1] in the January issue of the JOURNAL OF ENGINEERING EDUCATION, and that of Professor Guillemin[2] in the March, 1945 issue.

The accompanying need for improved correlation between mathematical and electrical engineering courses in the educational structure has already been well stated by Dr. Brennecke. Dean Justice has told you of correlation of mathematics and mechanics in the freshman year and first two terms of the sophomore year at the University of Cincinnati. With minor exceptions, this correlation is common to all engineering students. In the third term of the sophomore years the elec-

* Presented at the Joint Meeting of the Mathematics Division and Electrical Engineering Division, at the Annual Meeting of the A.S.E.E., Minneapolis, June 18–21, 1947.

[1] Bewley, L. V., "The New Curriculum in Electrical Engineering at Lehigh University": *J. E. E.*, Vol. 32, No. 5, January, 1942, page 434.

[2] Guillemin, E. A., "The Coordination of the Work of the Physics, Mathematics, and Electrical Engineering Staffs in the Formulation of Communications and Electronics Curricula, Including Ultrahigh-Frequency Techniques": *J. E. E.*, Vol. 35, No. 7, March, 1945, page 401.

trical engineering student starts to specialize in his chosen field and in the mathematics useful to him either in direct application or as training in analytical thinking.

It is my present purpose to discuss typical courses of a correlative type which may be found in the revised electrical engineering curriculum at Cincinnati where broad fundamental background is a prime objective. It should be mentioned that the shorter terms and more frequent intermissions in the form of work-sections make it possible to give the cooperative student a more intensive curricular schedule than would be feasible for a student attending classes eight or nine consecutive months during the year. Thus the five-year cooperative electrical engineering program at Cincinnati contains a total of more than 4100 contact hours, and is believed to be greater than that of any standard four year curriculum.

The sophomore course called Graphical Methods to which Dr. Justice referred carries over into the third term. It is extremely useful in helping the student bridge the gap between the more precise analytical methods he has learned through the Calculus and more practical methods of effective compromise which are of necessity found in modern engineering.

Another sophomore course of value is a lecture course entitled Applied Kinematics, accompanied by a Kinematics Design Laboratory. The lectures start with vector calculus and deal with the analysis of simple mechanisms in plane motion. Vector methods are used exclusively in anticipation of their need in field theory. The laboratory course includes the development of simple speed-time schedules for electric railway transportation, and the design and drawing of simple electrical devices such as circuit breakers, pantograph switches, and motion picture mechanisms.

For three terms in the pre-junior year the student of electrical engineering gets his most important applied mathematics course. It is called Mathematical Methods in Electrical Analysis and is intended to accomplish two broad objectives: first, the ability to formulate and interpret physical situations in mathematical terms by the use of fundamental principles; and second, a working knowledge of the technical tools of modern mathematical methods. This philosophy of teaching both the qualitative and quantitative aspects of mathematics is substantially that discussed by Professors Bryan,[3] Miller,[4] Grinter[5] and Synge[6] in previous issues of the JOURNAL OF ENGINEERING EDUCATION.

The actual content of this course is comprised of the following subject matter:

1. Review of basic principles of mechanics and their electrical analogies, dual systems, lumped parameters and need for ordinary differential equations.
2. Ordinary linear differential equations with constant coefficients, graphical and numerical methods,

[3] Bryan, Noah R., "Improving the Mathematics Preparation for Specializing in Technical and Scientific Fields": *J. E. E.*, Vol. 34, No. 10, June, 1944, page 664.

[4] Miller, Frederic H., "Mathematics Beyond Calculus for Engineering Students": *J. E. E.*, Vol. 37, No. 4, December, 1946, page 330.

[5] Grinter, L. E., "Teaching Mathematics to Engineers": *J. E. E.*, Vol. 37, No. 7, March, 1947, page 536.

[6] Synge, J. L., "Undergraduate Preparation for Graduate Study . . . Through Applied Mathematics": *J. E. E.*, Vol. 37, No. 7, March, 1947, page 531.

vector representation of damped sinusoids, application to single and double energy transients, amplitude modulation and beat phenomena.

3. Distributed parameters and need for partial differential equations, linear homogenous equation for the ideal line, traveling wave solution and boundary conditions for D.C. line, separation of variables and standing wave solution for A.C. line.
4. Synthesis of complex wave forms, Fourier series analysis, principle of superposition, applications to circuits with harmonic distortion, harmonic analysis. Exponential form of Fourier Series, the Fourier Integral and frequency spectra, application to ideal transmission systems.
5. Series solution of differential equations, Bessel and Gamma functions, application to eddy currents, skin effect and freqency modulation.
6. Heaviside operational calculus and Laplace transform analysis, comparison with previous methods of transient and steady state analysis of circuits and lines.

The amount of time devoted to individual topics is roughly proportional to their subsequent need and importance. Two texts have been used with notable success in conjunction with this course: *Advanced Mathematics for Engineers* by Reddick and Miller, and *Mathematical and Physical Principles of Engineering Analysis* by Johnson.

A course in Field Theory runs collaterally during the third term and stresses the vector analysis of fields, Maxwell's equations and Poynting's theorem. Also, a Transients Laboratory course is a valuable adjunct in correlating the analytical methods of transient analysis with laboratory results. Experimental methods in studying recurring and non-recurring transients in linear circuits are carried out giving the student incidental experience with oscillographic and photographic techniques.

By this time the student has an adequate mathematical preparation for the electrical courses of the junior and senior years. Junior courses requiring this preparation to a greater degree than others include Transmission Networks, Networks Laboratory, Transmission Line Theory, Electric Power Transmission, and Unbalanced Polyphase Systems.

At the senior or early graduate level it is difficult to cite certain courses as typifying correlation more than others since the majority of electives are essentially mathematical in their approach, whatever the student's option. This would include Servomechanisms, Electron Inertia Effect and Ultra High Frequency Techniques, Radiation and Propagation, Engineering Acoustics, Matrix Analysis and Tensors. In the majority of these courses the mathematics and electrical engineering are inseparable, making it impossible to distinguish where the one begins and the other ends.

Undoubtedly some will say that this is carrying things too far; that it is unnecessary to subject a student to so much "high-powered" mathematics as an undergraduate. Industry itself is divided on the subject. In the May, 1943 issue of the JOURNAL OF ENGINEERING EDUCATION, a paper by Mr. Stevenson [7] of the General Electric Co.

[7] Stevenson, A. R., Jr., "What Mathematical College Training Industry Expects from Young Engineers": *J. E. E.*, Vol. 33, No. 9, May, 1943, page 670.

entitled "What Mathematical College Training Industry Expects from Young Engineers" said in part: "It will be necessary to omit from the undergraduate engineering course specialized subjects such as Heaviside's method of solving differential equations, vector analysis, tensor analysis, special courses in circuit analysis etc., all of which are valuable but should be postponed to post-graduate years either in college or in industry for those with special aptitudes along these lines."

With this I most heartily disagree! One need only to sample random copies of such professional journals as *Electrical Engineering* and *I.R.E. Proceedings* to realize what mathematical equipment the serious technical reader is expected to have. It becomes obvious too that the situation involves more than just "tricks of the trade" to be learned on a co-op job or after graduation. Perhaps it is because of this need that so many graduates of former years feel like mathematical illiterates and are expressing their desire for courses in advanced mathematical methods from our evening colleges and industrial training programs.

It is evident that effective applied mathematics in electrical engineering courses can be taught best by faculty members having training in both fields —a sort of "mathematical engineer." At Cincinnati this is accomplished in two ways. The Department of Mathematics is large and its personnel has been selected from all fields of engineering and science, whereas the Electrical Engineering Department has several members who have special qualifications in graduate mathematics. In addition, both departments have representation on the teaching staff of the Graduate Department of Applied Science, thereby securing a fuller perspective and appreciation of the need for both inter- and intra-departmental correlation.

While there may be a diversity of opinion concerning the details of curricula at particular schools, there are underlying principles of correlation independent of institutions. In addition to the natural coordination between classroom and laboratory courses in electrical engineering, there is an ever-growing need for judicious correlation with mathematics. Such correlation pays great dividends in the amount of subject matter which can be covered adequately and effectively, a situation which the present and future demand.

Engineering Mathematics*

By V. G. SMITH

Professor of Electrical Engineering, University of Toronto

In speaking of "Engineering Mathematics" to a group composed largely of university teachers, one naturally tends to restrict the subject somewhat to the teaching of mathematics to engineering students. Most of my remarks will be along that line but I first wish to make a few general observations.

Thinking of engineering mathematics, one might easily ask why the mathematics of engineering should be in any way special. The answer seems to be largely in the point of view. For engineers, mathematics is a tool used to find the answer to some question or questions and not an end in itself. They have at their disposal other means of finding answers to questions; model construction, experimental measurement, and graphics, any and all of which are combined with each other and with mathematics. One of the arts of engineering is in deciding just what combination of methods will yield the required answers with the least total effort.

Another respect in which engineering mathematics differs is this. Applied mathematicians frequently simplify a particular problem and find a general solution which covers a large number of cases, none of which quite agrees with the original problem. Such solutions are often of great utility and usually can be made the basis of more exact solutions by improved approximations. The engineer, however, must usually, for economic reasons, secure a sufficiently exact numerical solution to a particular problem, however inelegant his methods. I have, for example, several times spent up to three weeks at six and three-quarter hours a day computing what the power system of the H.E.P.C. of Ontario would do in one second. Such problems account for the building of expensive network analysers, differential analysers, and elaborate computing machines.

Finally, in engineering mathematics the special cases and exceptions (which are often the most difficult part of formal mathematics) seldom arise. Thus an engineer is quite safe in taking Fourier's Theorem to be "*Any* periodic, single-valued function may be expanded . . . ," and I have never seen a practical case in which the remainder of a Taylor's series did not vanish when the series itself converged. This does not mean that the engineer should be left in ignorance of the exceptions; they should be pointed out, preferably with examples, but with very little time spent on them.

While at the undergraduate level one can notice a great difference in the required mathematics of the various branches of engineering, this difference disappears at the graduate level. Modern electrical engineering seems to re-

* Reprinted from the Proceedings of the *Canadian Mathematical Congress*, Montreal, June 18–23, 1946.

quire a more extensive knowledge of mathematics than the other branches but they are rapidly catching up. A good communication specialist should have a sound working knowledge of circular, exponential, hyperbolic, and Bessel functions for real and complex variables, together with the differential equation and function theory background. Fourier analysis is essential and Laplace transforms or operational methods are desirable. Vector analysis is pre-requisite to electromagnetic theory and determinants and matrices are a necessary background.

A word of caution might be inserted here. We have been talking of a rather small class of engineers; the technical specialists, the research type. Often this is the only type in which mathematicians are interested but there must be many engineers doing work of a lower mathematical standard, or even none at all, for each research engineer.

Engineering Physics at Toronto. Dr. Pall has asked me to say something about the Engineering Physics Course at Toronto. This course was organized in 1935 and commenced that autumn with *seven* students; last September, *forty-four* students entered the course. Only students with first class honours in Grade XIII Mathematics and a high general average are admitted, consequently the average ability of the group is very high. There are, however, students just as able in the ordinary engineering courses, a fact which is sometimes overlooked. The first two years of the Engineering Physics Course are common but in the third year there is some division depending upon the fourth year option chosen.

The engineering physics students take most of their mathematics and physics with the Arts mathematics and physics students and so absorb the atmosphere and enthusiasm of the arts faculty for those subjects. On the other hand they spend most of their time with the engineering students and get the viewpoint of engineering. The net result is that they are highly critical of many features of both sides of the road; to the ultimate benefit, I am sure, of both. Certain it is that each engineering physics student has to do a lot of weighing, comparing, and judging that ordinary students of either arts or engineering never do. That these students are having an effect upon the ordinary engineering students is shown by student suggestions for course improvements and that they have an effect upon physics students is shown when ten arts students cross the road to take engineering lectures.

There is no point in trying here to compare in detail the Engineering Physics Course with the other engineering courses but some remarks may be of interest.

In the third and fourth year, subjects can be given to the Engineering Physics students which are too mathematical for the other courses, such as electromagnetic theory to the Electricity and Communication Option. On the other hand that option misses, owing to lack of time, hydraulics, heat engines, business machine design, engineering law, and the lectures on alternating current machinery, but not the laboratory. Note that it is the mechanical subjects which have suffered. Only a close study of the calendar will disclose all the differences.

Personally, I regard the Engineering Physics Course as the best preparation we offer to men who have the necessary qualifications and who wish to become technically expert with a view to research work of some kind, though I

realize quite well that some of my colleagues would disagree with me. The one universal criticism and real fault with the course is that it is too crowded and that the student does not have time to think. I believe that this is true, but just try to get agreement, even among the students, on the proper subjects to remove!

Undergraduate Engineering Mathematics. Before speaking on the subject of undergraduate engineering mathematics, I should state that I have never taught first or second year mathematics except incidentally in a course on electrical circuits and measurements. I am therefore speaking as one who is dealing with the product of the usual undergraduate mathematics course.

It will be admitted by all concerned, I think, that the percentage of failures in the first year calculus and analytical geometry and in the second year calculus at Toronto is very high. Probably this is the same in other institutions. But we find the same thing occurring when dynamics and statics are taught from an analytical viewpoint and problems requiring real thinking are set. What then is the answer?

I never think of this question without coming to the conclusion that the range of student ability is too great for a single class and that there should be some form of separation into at least two groups, call them honours and pass or what you will. Some students complain that not enough new material is presented in the second year calculus and yet the failures are many. Some professors of mathematics and physics seem to feel that the elimination of these poor mathematical students from engineering is all to the good. In many cases this is true, but we must never forget that engineering is a broad field and many mathematically mediocre students of the past are doing excellent work in executive, manufacturing, and sales positions. By the way, it *does* require a trained engineer to sell some engineering products intelligently.

Apart from the range of ability I feel that one of the chief difficulties in teaching undergraduate engineering mathematics is the general lack of interest and enthusiasm on the part of engineering students for the subject. Whether this fault lies with the students, the engineering staff, or the mathematics staff I cannot undertake to say, for the engineering staff arouses considerable student interest in other subjects and the mathematics staff certainly arouses interest in mathematics among the engineering physics and arts students. Probably the dice are loaded that way by the student selection of their courses in the first place. But are there not ways of arousing more interest in mathematics among engineering students?

Why not introduce each new idea in an easily visualized physical problem? For example, differentiation as the problem of the policeman measuring the speed of an automobile going down the street or the problem of the surveyor measuring the slope of a hill, integration as the problem of finding the capacity of a wine cask. Personally I have always had extreme difficulty in learning any mathematics just because I wanted to learn it, but have usually found it very easy when it was incidental to some physical problem. Perhaps others are the same.

The fundamental concepts of the elementary calculus are really quite easy to grasp but traditionally the subject is regarded as difficult, as a hurdle that must be jumped and then for-

gotten. In the past both the staff and practising graduates of engineering have not been guiltless of fostering this unfortunate tradition. Such ideas are now rapidly disappearing. To those teaching the elementary calculus may I suggest that they treat it from an application point of view *at first*, tie it to physical problems, and make sure their assumptions correspond closely to nature, and divorce it as much as possible from geometry, which is itself difficult to many engineering minds. The separation of the calculus from physical problems at a later stage should be more or less natural. In this way it is believed that a greater interest would be aroused. I really learned to appreciate what the calculus was all about in hydrostatics, working out centres of pressure, centres of buoyancy, etc. The integrations were simple enough and the overall picture became clear.

In teaching elementary differential equations always introduce three or four problems which depend upon its solution *before* finding the solution. In more advanced work the problems can be taken simply as examples. Thus in Bessel functions we may consider the Fourier analysis of an elliptical wave, the side bands of a frequency modulated signal, and any wave problem having cylindrical symmetry as typical examples.

I realize, of course, that the question of physical problems is a delicate one. The mathematics teacher is often not too familiar with them, nor indeed too interested in them, and he is always a bit afraid of stepping on someone's toes should he choose dynamics problems or electric circuit problems. Surely here is a place for cooperation between the staffs.

How about the early incidental *use* of complex numbers and elementary complex functions in a purely formal manner, almost as though no special investigation were necessary? This subject always seems to arouse student interest and few special rules are involved; and perhaps the mathematicians will deign to use the hated j (which was introduced by a mathematician), at least until the engineering profession has learned to use i. Hyperbolic functions should be used freely. Define them and derive their properties as you need them. Most students have short tables of these functions and are inquisitive about them. Why should integrals which are most naturally expressed in hyperbolic functions or their inverse, be always expressed as combinations of exponentials or complicated logarithms?

Many students fail in calculus in part at least because of lack of facility in algebra. A brief review of the laws of algebra does, I know, arouse interest, especially as emphasis can be laid upon the philosophy of the steps from arithmetic algebra to symbolic algebra and from positive integral indices to fractional and negative indices, including the binomial theorem, which most students have never taken generally. Later the exponential and logarithmic functions can be derived without too much attention to rigour and the calculation of some logarithms set as an exercise. These things can be done in an incidental manner and need not absorb too much time.

I firmly believe that every mathematician should do some calculating for the good of his soul. Often a clearer understanding of a problem is obtained in this way than can be obtained in any other. Many correct formulas are unsuited to computation and much ingenuity is often needed to overcome

this. One of the first shocks that many mathematicians experience is to find that convergent series are usually quite useless for practical computations. Engineering students in particular require numerical examples. If the problem has an algebraic solution, particular numerical cases should be worked out or set as problems.

The arousing and maintaining of interest in mathematics is one of the chief problems in teaching engineering students. Perhaps some of the suggestions made here will help.

Lastly there is one ridiculous obstacle to mathematics for many engineering students; the Greek alphabet. The late Professor T. R. Rosebrugh introduced the so-called general circuit constants into electrical engineering and called them α, β, γ, δ. Some years ago I suggested to him that he change to a, b, c, d, as had become common usage elsewhere, on the grounds that whereas the average student knew no Greek, he was supposed to know his a, b, c's. The scheme seemed to work. I suggest that each engineering student be required to memorize the Greek alphabet and learn how to write it himself. Ridiculous as it is, I think it would help.

Teaching Engineering Gyroscopics

By WILLIAM R. WEEMS

Assistant Professor of Aeronautical Engineering, Massachusetts Institute of Technology

Although the gyroscope is familiar to everyone as a toy and to some as a mathematical exercise, its practical exploitation has been in progress only since early in the 20th century. Nevertheless, it has already achieved general acceptance as being uniquely qualified to perform many essential functions. At the same time, there seems to be a widespread feeling, even among engineers, that there is something mysterious about a gyroscope. Many do not make any attempt to understand it and teachers are handicapped by paucity of text material and the general mental block that seems to spring up whenever three-dimensional problems are encountered.

In view of the ever-increasing importance of gyroscopes, it is likely that more and more teachers will be including a treatment of gyroscope theory in their courses. Therefore, it may be helpful to consider briefly the approach that has been evolved at M.I.T., where gyroscopic theory has been taught and utilized in research and development projects for a number of years. This approach is embodied in the unique presentation of gyroscopic theory which has been developed by Dr. C. S. Draper, Director of the Instrumentation Laboratory at M.I.T. It effectively removes the aura of mystery from the gyroscope and transforms it into an easily understood and precise element of instrumentation.

This presentation is characterized by an initial analysis of the most general gyroscope situation of engineering interest, from which all subsequent applications of the gyroscope can be explained by specialization. Thus the student is helped to understand each gyro device studied and to relate each to the others, keeping in mind always the essential physical laws common to all gyroscopes. This is in contrast to the lack of perspective, if not actual confusion, resulting from the more usual presentation of the subject, wherein each application is analyzed as an isolated problem.

The obvious advantages of the generalized presentation might be seriously diminished by its complexity if it were not for the use of methods designed or chosen to assist the mind in handling the *three-dimensional* concepts involved. The word *three-dimensional* should be stressed because it appears that all of the common difficulties encountered in teaching the subject have their roots in the fact that it deals with three dimensions simultaneously, while the students are generally unfamiliar with reasoning in more than two dimensions. The methods used assist the mind by:

(1) Simplifying the graphic representation of the problem.
(2) Releasing the mind from the limitations of having to think in

terms of components along coordinate axes, so that it can concentrate on the physical aspects of the problem.

(3) Incorporating a system of symbols which implies the essential qualities of the physical quantities involved, including similarities and differences among them.

Item (1), simplification of the graphic presentation, is accomplished first of all through the representation of essential quantities as vectors, using the usual right hand sense rule. Thus, a torque is represented by a vector along its axis and is referred to as a torque "about such and such an axis" rather than a torque "in such and such a plane." Only those who have tried to draw free hand sketches of gimbal systems and gyro wheels on short notice can appreciate fully the simplification that can be effected by reducing everything with vector properties to actual vectors in the graphical representation. A second type of simplification is effected in the mathematical analysis by the free use of Euler's angles to express the relationships among the various frames of reference that are required in analyzing the gyroscope.

Item (2) is accomplished by utilizing the powerful notation of vector analy-

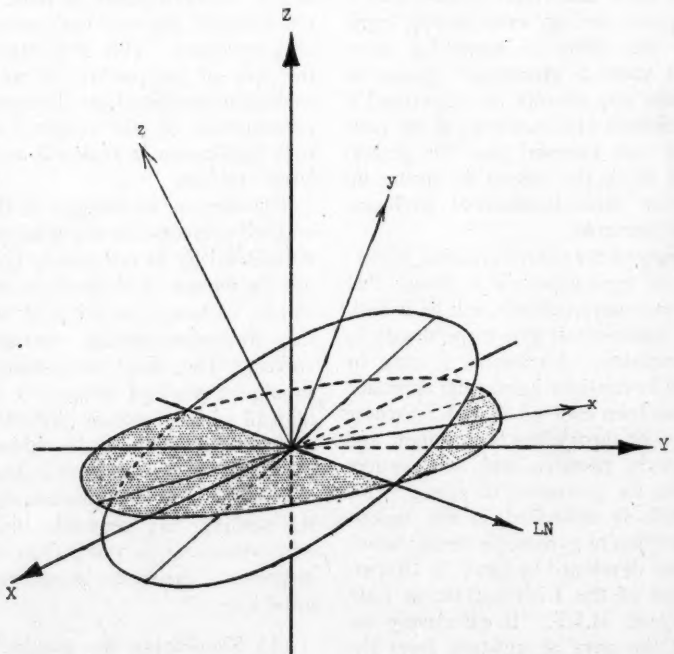

FIG. 1

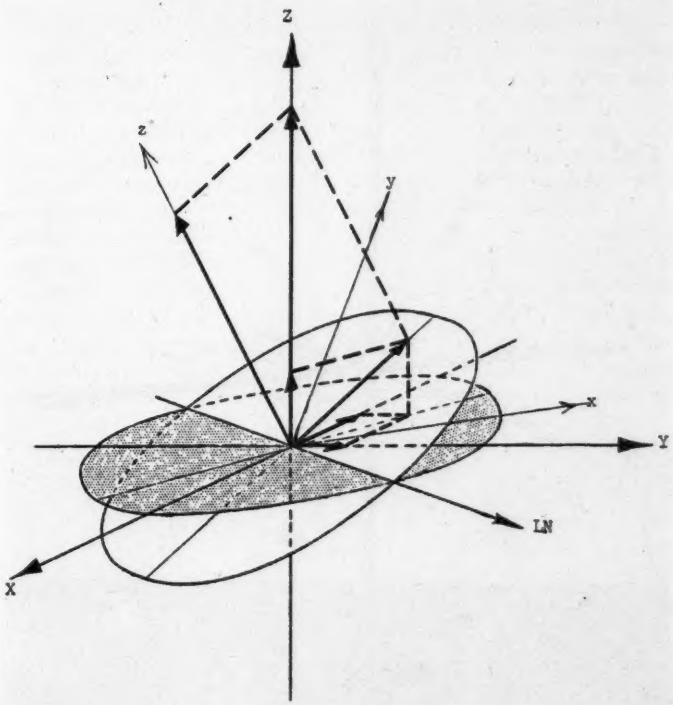

FIG. 2

sis. Although this is unfamiliar to many engineering students, a little practice in the simpler aspects of it normally serves to win them over to its great utility in doing the bookkeeping of components and trigonometric resolutions automatically. Actually, the only vector operations that are required are addition and subtraction, scalar and vector products, and differentiation of a vector; the more difficult operations used in analyzing field problems are not needed.

Item (3) refers to a sytem of symbols involving multiple subscripts. It is beyond the scope of this paper to go into the details of the system, but the basic idea of multiple subscripts is commonly known. The involved dynamical and geometrical situations connected with gyroscopic analysis merely call for a certain degree of codification of the system in seeking the maximum utility.

It may seem to one not familiar with the situation that the type of presentation outlined would require the devotion of an undue proportion of the time to familiarizing the student with fundamental concepts implicit in the notation and symbols used. It is true that a considerable proportion of the time has to be spent on these fundamentals. But it has been found that,

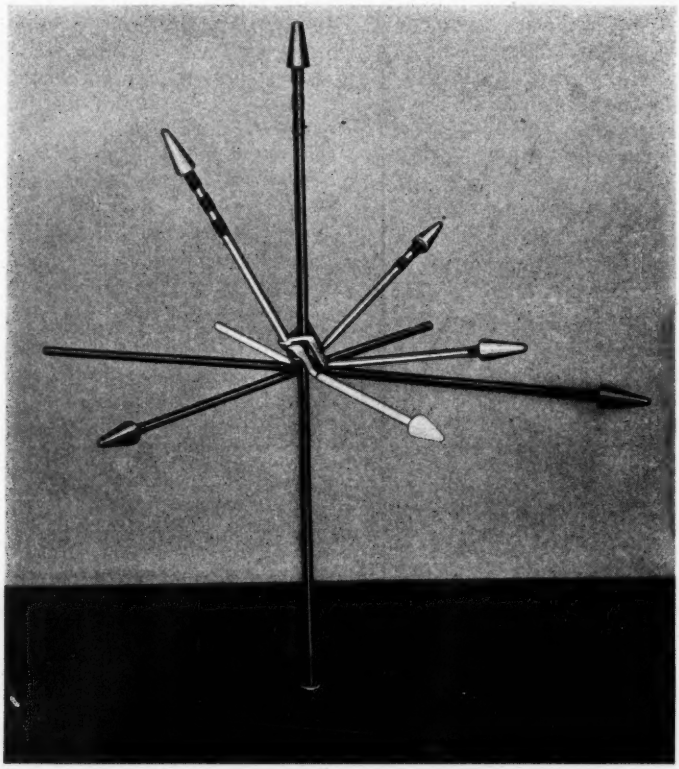

FIG. 3

instead of hindering, this actually helps the student in obtaining a clearer and firmer understanding of the gyroscope within the allotted time. Once these fundamentals have been mastered, for example, the key to almost all engineering analyses involving the gyroscope is the simple and concise equation

$$\bar{M}_{(\text{app})} = \bar{W}_{IFi} \times \bar{H}.$$

In this expression, $\bar{M}_{(\text{app})}$ is the applied torque, $\bar{W}_{IFi}$ is the angular velocity of the inner gimbal with respect to inertial space and $\bar{H}$ is the angular momentum of the gyroscope (all vector quantities).

If it is granted, then, that the analysis of an inherently three-dimensional problem properly involves the use of three-dimensional tools, even though they may be unfamiliar at first, there still remains the pedagogical problem of how to get these unfamiliar ideas across with the minimum of confusion. The principal difficulty does not lie in the notation of vector analysis itself; there are numerous good references on this subject, and a rather shallow penetration of them is adequate for this purpose. The real difficulty lies in visualizing and organizing the three-dimen-

sional picture. This applies particularly to the familiarization with Euler's angles and the derivation of the various sets of transformation equations involved in referring vector quantities expressed in terms of different sets of coordinates related by Euler's angles. Most teachers, and certainly most students taking notes, are not good free-hand artists. Our blackboards and note paper are definitely two-dimensional. Indeed it is quite possible, especially at the beginning of a course, for the teacher to draw what he considers a clear sketch of a three-dimensional situation and then have to spend half of the hour dispelling the optical illusions of various students.

A satisfactory answer has been found in the use of a few three-dimensional models, fortified by mimeographed sketch sheets supplied to the student. These sketch sheets furnish the student the same basic construction lines the teacher habitually uses in sketching situations on the blackboard. One of the blank sketch sheets is illustrated in Fig. 1. Fig. 2 depicts the same sheet containing a sketch used in a classroom derivation. To assist instructors in preparing sketches for classroom presentations which will be neat and easily

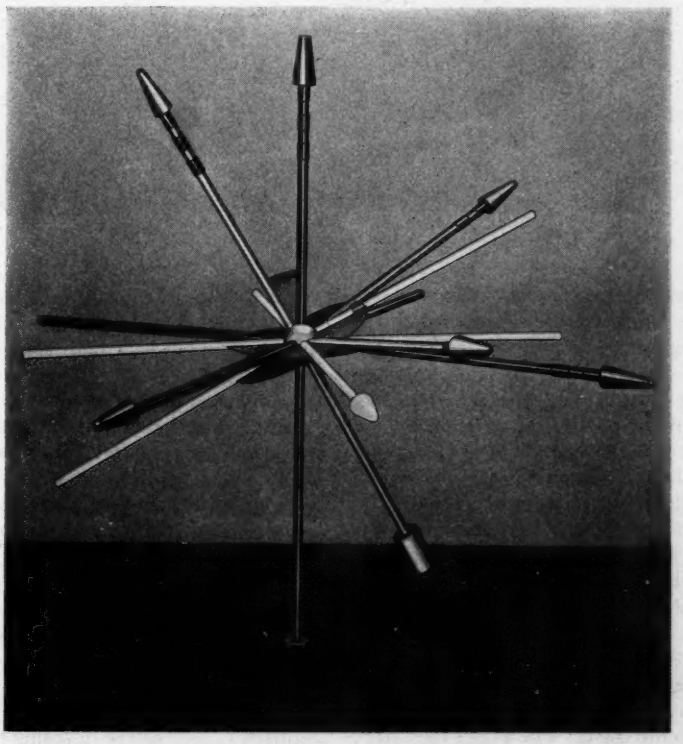

FIG. 4

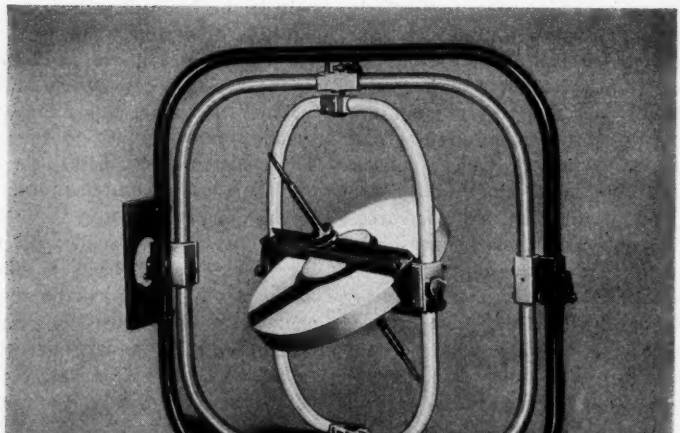

FIG. 5

copied on the students' sketch sheets, there has even been prepared a special light blackboard panel about three feet square, with permanent sketch guide lines on it. These guide lines are an enlargement of those on the students' sketch sheets and are drawn on the black surface with india ink, so that they are quite clear to one close up but not noticeable to one a few feet away.

In illustrating lectures and in actually working out certain basic three-dimensional resolutions, the space models of Figs. 3 and 4 are used. These models show a set of reference axes (X, Y, Z of Figs. 1 and 2), with another set of axes (x, y, z) arbitrarily oriented with respect to them. The angles used to relate the two sets of axes are Euler's angles. Fig. 3 depicts a model in which the various lines are represented by metal rods which actually move in appropriate sets about the correct axes to duplicate, within the limits of mechanical interference, the angular displacements represented by the three Euler's angles. In Fig. 4, all rods are fixed, allowing the attachment of transparent panes to assist the eye in organizing the picture. These panes furnish a convenient means of labeling the angles, and the fixed rods are useful for illustrating trigonometric resolutions by means of colored adhesive tapes stretched from point to point. In both models vivid and contrasting colors are utilized to aid the eye in seeing the axes in sets.

The most useful model of all—one which is used during all phases of the subject—is the one illustrated in Fig. 5. This is a working model gyroscope which operates on ordinary 60 cycle current and which is designed specifically for the teaching job. It makes use of vivid colors to differentiate the various frames and is fitted with a number of attachments which provide means for applying torques to the gyro element, means for measuring angular displacements, and means for altering the non-rotating inertias by definite amounts. Provision is made, also, for locking any two consecutive frames together as desired and for orienting the gimbal system in various ways with respect to the vertical. The rotor is a heavy wheel that rotates slowly enough that a reference stripe on it can be seen by the students at all times. This slow speed is used primarily to enable an observer to sense the direction and speed of rotation, but has a secondary advantage in that it causes the nutational frequencies to be low enough for oscillations to be timed by use of visual observations and a stopwatch in covering that aspect of gyroscopics. The demonstration gyroscope is used, not only to illustrate lectures, but also in the laboratory for experiments which emphasize the *quantitative* aspects of gyroscope theory. For this purpose, the gyro model is used in conjunction with a motor-driven turntable for furnishing forced precessions. It is usual, and of course highly desirable, for the students taking the theoretical work on gyroscopics to take a concurrent laboratory course which contains a number of experiments designed to buttress the theoretical coverage.

Another short article, describing these teaching aids in more detail, is contemplated for the near future. Questions, criticisms and suggestions are invited, as they will be helpful in its preparation.

Comments on Mechanics Analysis

By R. M. COOK

Assistant Professor of Civil Engineering, Northwestern University

Professor Wyly's notes on the philosophy of stress analysis in the JOURNAL OF ENGINEERING EDUCATION, Vol. 37, April, 1947, needs some comment. While no one can disagree with his emphasis on the importance of signs in the analysis of indeterminate problems such as the bent illustrated in Fig. 2 of his article the writer wonders if the emphasis placed on the importance of signs in the analysis of the simple problems is justified.

Signs in the writer's viewpoint are a necessary evil of much of the theoretical work of the engineer. Signs are given to moments, forces and rotations in those cases when there is doubt as to the direction of the moment, force or rotation.

In the case of the simple beam where the direction and magnitude of the reactions are practically obvious, signs in the writer's experience are "confusers" and "mistake makers." Part of this viewpoint from the writer's standpoint is due to his concept of the equilibrium relations which he wishes to emphasize here.

Primarily the equations $\Sigma M = 0$, $\Sigma V = 0$, and $\Sigma H = 0$ are "balancing equations." In other words they say (1) that the sum of the moment of forces about one axis in one direction must be balanced by an equal sum of moment of forces in the opposite direction about the same axis, (2) that the sum of forces pushing a body *up* must be equal and balance the sum of the forces pushing the body *down*, (3) that the sum of the forces pushing a body to the *left* must be equal and balance the sum of the forces pushing the body to the *right*.

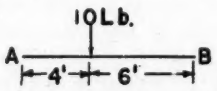

FIG. 1.

The writer has felt for many years that our textbooks lose this visual concept of "balance" that is so important in the analysis of problems in statics by cluttering up our equations with a large group of numbers equal to 0. We would do better to write our equations as balancing equations placing our equal sign in the middle.

For illustration let us look at the simple beam of Professor Wyly's article (Fig. 1).

If the support at A were removed the beam would collapse but the collapsing would be in the form of rotation about B (Fig. 2). Therefore it seems very logical to "balance" moments of forces about an axis through B to determine the force needed at A to place the beam in equilibrium. The equation $\Sigma M_B = 0$ would then be written as a balancing equation $10 \times 6 = V_A \times 10$, solving then $V_A = 6$ lbs. and the direction of V_A is such as to prevent rotation of the beam about B.

"Balancing" vertical forces then, 10 lbs. acting down must be balanced by 10 lbs. acting up, then $10 = 6 + V_B$ or $V_B = 4$ lbs. acting up as shown in Fig. 3.

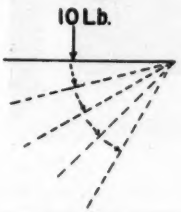

FIG. 2.

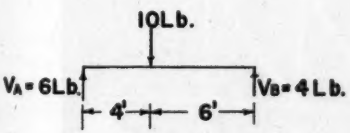

FIG. 3.

The statement in most mechanics books that counter-clockwise moment is to be considered positive, the writer believes is confusing to students, for in their strength of materials course and structural courses they find other conditions govern the sign of moments of forces. The writer, therefore, believes that this statement could be omitted from mechanics books and emphasis placed on conditions of balance rather than signs.

To carry this concept of balance a little further models of some simple structures have been found helpful. If the student can properly visualize the action of a structure upon the removal of a constituent member the proper axis about which to balance moment of forces is practically obvious as that axis about which the structure would rotate in collapsing.

For example, Fig. 4 is a simple Pratt through bridge truss with a load at joint *D*.

If we wish to know the force in member *CD* just remove member *CD* and note the collapse of the structure. In collapsing the structure would sometime assume the shape in Fig. 5. It seems obvious that member *CD* is a tensile member and that the normal axis through joint *A* is the proper axis about which moment of forces should be balanced to determine the force in *CD*.

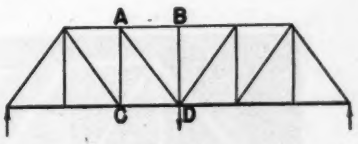

FIG. 4.

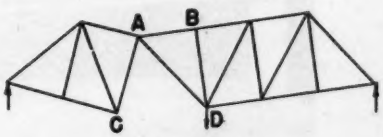

FIG. 5.

The writer has developed a model for use with students in mechanics to illustrate this point and other points. The model is a small Pratt truss with flexible members any or all of which can be blocked out with solid members.

Fig. 6 is a photograph of the model with a load at joint *G* showing the sag of the whole structure, compression in the top chord, tension in the lower chord, and the tension and compression coming in the diagonals and verticals. The model exaggerates the deformation and is used purely for illustration purposes.

Fig. 7 is a photograph of the model with every member blocked out with solid members, except member *DF*. As the structure is collapsing by rotation about an axis through joint *G*,

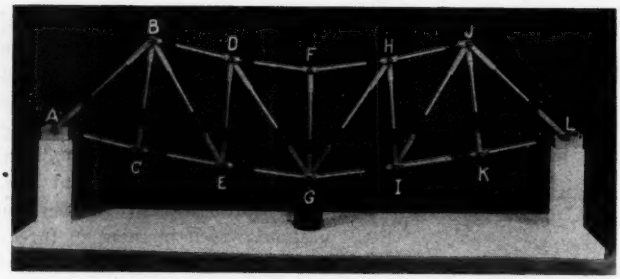

FIG. 6

FIG. 7.

it would be logical to balance the moments of forces about this axis to determine the force in *DF*.

While the principles presented in this article are not particularly new the writer believes they are extremely helpful to the beginning student in mechanics and should be emphasized.

While no one can argue the importance of the proper handling of signs in indeterminate stress analysis using the Moment Area or Slope Deflection relations, the writer believes that training in visualization and application of the principle of balance thereto is of prime importance in the field of mechanics.

Canons of Ethics for Engineers

The Canons of Ethics for Engineers were prepared by the Committee on Principles of Engineering Ethics of the Engineers' Council for Professional Development. Members of this committee, representing all of the constituent societies, collaborated in the preparation of the final draft. The Canons have been approved by the Council of the Engineers' Council for Professional Development and will be officially adopted when approved by the constituent societies. They were approved by the General Council of the American Society for Engineering Education at its meeting in Washington on November 11, 1947.

Foreword

Honesty, justice and courtesy form a moral philosophy which, associated with mutual interest between men constitutes the foundation of ethics. The engineer should recognize such a standard, not in passive observance, but as a set of dynamic principles guiding his conduct and way of life. It is his duty to practice his profession according to these Canons of Ethics.

As the keystone of professional conduct is integrity, the engineer will discharge his duties with fidelity to the public, his employers and clients, and with fairness and impartiality to all. It is his duty to interest himself in public welfare, and to be ready to apply his special knowledge for the benefit of mankind. He should uphold the honor and dignity of his profession and also avoid association with any enterprise of questionable character. In his dealings with fellow engineers he should be fair and tolerant.

Professional Life

Sec. 1. The engineer will cooperate in extending the effectiveness of the engineering profession by interchanging information and experience with other engineers and students and by contributing to the work of engineering societies, schools and the scientific and engineering press.

Sec. 2. He will not advertise his work or merit in a self-laudatory manner, and he will avoid all conduct or practice likely to discredit or do injury to the dignity and honor of his profession.

Relations with the Public

Sec. 3. The engineer will endeavor to extend public knowledge of engineering, and will discourage the spreading of untrue, unfair, and exaggerated statements regarding engineering.

Sec. 4. He will have due regard for the safety of life and health of the public and employees who may be affected by the work for which he is responsible.

Sec. 5. He will express an opinion only when it is founded on adequate knowledge and honest conviction while he is serving as a witness before a court, commission or other tribunal.

Sec. 6. He will not issue ex parte statements, criticisms or arguments on matters connected with public policy which are inspired or paid for by private interests, unless he indicates on

whose behalf he is making the statement.

Sec. 7. He will refrain from expressing publicly an opinion on an engineering subject unless he is informed as to the facts relating thereto.

Relations with Clients and Employers

Sec. 8. The engineer will act in professional matters for each client or employer as a faithful agent or trustee.

Sec. 9. He will act with fairness and justice between his client or employer and the contractor when dealing with contracts.

Sec. 10. He will make his status clear to his client or employer before undertaking an engagement if he may be called upon to decide on the use of inventions, apparatus, or any other thing in which he may have a financial interest.

Sec. 11. He will guard against conditions that are dangerous or threatening to life, limb or property on work for which he is responsible, or, if he is not responsible, will promptly call such conditions to the attention of those who are responsible.

Sec. 12. He will present clearly the consequences to be expected from deviations proposed if his engineering judgment is overruled by non-technical authority in cases where he is responsible for the technical adequacy of engineering work.

Sec. 13. He will engage, or advise his client or employer to engage, and he will cooperate with, other experts and specialists whenever the client's or employer's interests are best served by such service.

Sec. 14. He will disclose no information concerning the business affairs or technical processes of clients or employers without their consent.

Sec. 15. He will not accept compensation, financial or otherwise, from more than one interested party for the same service, or for services pertaining to the same work, without the consent of all interested parties.

Sec. 16. He will not accept commissions or allowances, directly or indirectly, from contractors or other parties dealing with his client or employer in connection with work for which he is responsible.

Sec. 17. He will not be financially interested in the bids as or of a contractor on competitive work for which he is employed as an engineer unless he has the consent of his client or employer.

Sec. 18. He will promptly disclose to his client or employer any interest in a business which may compete with or affect the business of his client or employer. He will not allow an interest in any business to affect his decision regarding engineering work for which he is employed, or which he may be called upon to perform.

Relations with Engineers

Sec. 19. The engineer will endeavor to protect the engineering profession collectively and individually from misrepresentation and misunderstanding.

Sec. 20. He will take care that credit for engineering work is given to those to whom credit is properly due.

Sec. 21. He will uphold the principle of appropriate and adequate compensation for those engaged in engineering work, including those in subordinate capacities, as being in the public interest and maintaining the standards of the profession.

Sec. 22. He will endeavor to provide opportunity for the professional development and advancement of engineers in his employ.

Sec. 23. He will not directly or indirectly injure the professional reputation, prospects or practice of another engineer. However, if he considers that an engineer is guilty of unethical, illegal or unfair practice, he will present the information to the proper authority for action.

Sec. 24. He will exercise due restraint in criticizing another engineer's work in public, recognizing the fact that the engineering societies and the engineering press provide the proper forum for technical discussions and criticism.

Sec. 25. He will not try to supplant another engineer in a particular employment after becoming aware that definite steps have been taken toward the other's employment.

Sec. 26. He will not compete with another engineer on the basis of charges for work by underbidding, through reducing his normal fees after having been informed of the charges named by the other.

Sec. 27. He will not use the advantages of a salaried position to compete unfairly with another engineer.

Sec. 28. He will not become associated in responsibility for work with engineers who do not conform to ethical practices.

Sections and Branches

The Ninth Annual Meeting of the **North Mid-West Section** of the American Society for Engineering Education was held in Milwaukee, Wisconsin, on October 17 and 18, with Marquette University acting as hosts. Rev. P. A. Brooks, S.J., President of Marquette University, delivered the welcoming address at the banquet. Other speakers included B. G. Elliott on the "Faculty Viewpoint on Engineering College Problems," in which he gave a report of the findings of the University of Wisconsin College of Engineering Planning Committee, and A. von Wening, Vice President and Controller of the A. O. Smith Corporation, on the "Place of the Engineer in Industry."

The new officers for the North Mid-West Section include F. L. Partlo, Chairman; C. J. Posey, Vice Chairman; and S. R. Price, Secretary and Treasurer. The following board members were elected: D. W. Nelson, E. W. Johnson, R. O. Kallenberger, and H. J. Stoever.

Technical papers included the following:

Civil Engineering: "The Practical Aspects of Soil Mechanics," Albert T. Bleck; "Soil Mechanics as Taught at the University of Wisconsin," George W. Washa; "Undergraduate and Graduate Courses in Soil Engineering at Iowa State College," M. G. Spangler.

Electrical Engineering: "Some Aspects of Charged Particle Machines," Walther Richter; "Measuring and Photographing Periodic Transients," C. J. Schjonberg; "Popularizing the Study of Magnetic Fields," J. F. H. Douglas.

Engineering Drawing: Round Table Discussion of Topics Relevant to the Teaching of Engineering Drawing. 1. Psychological Impact of Drawing on the Student Body. 2. When do Fundamentals End and

Specialization Begin? 3. Theory and Practice of Engineering Drawing.

Mechanical Engineering: "Industrial Viewpoint on Shop Courses," Richard Falk; "Is the Second Law Indispenable in Engineering Thermodynamics," H. J. Stoever; "Application of Fluid Mechanics to Machinery," Walter Ferris; "Considerations in the Teaching of Advanced Machine Design," R. J. Harker.

Theoretical and Applied Mechanics and Mathematics: "The Closer Relations of the Mathematics and Mechanics Departments," George C. Priester.

College Notes

The addition this October of nearly 150 new members brought the **University of Illinois College of Engineering** faculty to 468, the largest in its history. Appointments to the various professorial ranks include the following: as professor of physics, and dean of the graduate school of the University, Dr. Louis N. Ridenour; as visiting research professor in theoretical and applied mechanics, Dr. A. M. Freudenthal; as special research professor in ceramic engineering, Dr. W. R. Morgan; as professor of physics, Dr. A. T. Nordsieck; as part-time lecturer and research consultant in clay mineralogy in the department of civil engineering, Dr. R. E. Grim, photographer and principal geologist of the Illinois State Geological Survey; as associate professors in various categories—W. L. Hull, Everett Laitala and L. C. Pigage (mechanical engineering), Dr. H. L. Langhaar (theoretical and applied mechanics), and Dr. Henry Quastler (radiobiology, under physics); as assistant professors in various categories—G. F. Stockdale (ceramic engineering), L. G. Alexander (chemical engineering research), W. H. Munse, J. C. Dietz, E. R. Bretscher and E. J. Daily (civil engineering), Thomas A. Murrell (electrical engineering), Harry Czyzewski (metallurgical engineering), and R. D. Hill and Dr. R. D. Rawcliffe (physics). The foregoing will engage in research, at least part-time.

Additions to the teaching staff include: In aeronautical engineering, Associate Professor F. R. Stienbacher and Assistant Professor Jacque Houser; in electrical engineering, Assistant Professors D. S. Babb, J. R. Barkson, W. H. Byers, P. K. Hudson, J. P. Neal, and H. D. Webb; in mechanical engineering, Assistant Professor R. N. McDonald; in theoretical and applied mechanics, Professor N. O. Myklestad.

Professor Harold L. Walker, head of the department of mining and metallurgical engineering, returned in October from leave granted in April so that he might fulfill Governor Dwight Green's request that he serve as acting director of the State Department of Mines and Minerals.

Progress is being made in the construction of new buildings for the mechanical and electrical departments. The former staff hopes to have its structure available before February 1949. The electrical engineering building may be ready by September 1948. The mechanical building has a net floor

space of approximately 72,000 square feet, the electrical building of approximately 60,000.

The University of Illinois College of Engineering recently reported to the Engineering Experiment Station Record data on more than a dozen major projects, some new and some entering on significant new phases. These include betatron, cyclotron, highway drainage, and other investigations.

Cornell University announced the establishment of an endowed professorship of metallurgical engineering named for Francis Norwood Bard, owner of the Barco Manufacturing Company of Chicago. Mr. Bard made the formal presentation of a $250,000 fund to endow the professorship at a dinner in his honor.

The university also announced the appointment of Professor Peter E. Kyle as the first occupant of the chair, and redesignation of the School of Chemical Engineering as the School of Chemical and Metallurgical Engineering to place new emphasis on instruction and research in metallurgical engineering.

New Members

ANDERSON, HOWARD B., Instructor in Mathematics, Michigan College M. & T., Houghton, Mich. J. M. Harrington, W. A. Longacre.

ANDERSON, W. CARLISLE, Assistant Professor of Engineering Drawing, Univ. of Okla., Norman, Okla. F. S. Roop, R. V. James.

APPELGATE, JAMES M., Teaching Assistant, General Engineering, Univ. So. Calif., Los Angeles, Calif. K. C. Reynolds, L. R. Schruben.

BAKALER, ARNOLD, J., Instructor in Technical Drawing, Ill. Inst. Tech., Chicago, Ill. I. L. Hill, H. C. Spencer.

BELL, JOSEPH H., Instructor in Mechanical Engineering, Okla. A. & M. College, Stillwater, Okla. R. R. Irwin, E. R. Stapley.

BLACK, WINSTON E. Assistant Professor T. & A. M., Univ. of Illinois, Urbana, Ill. J. O. Smith, W. L. Collins.

BOCK, LESTER G. Lecturer in Mechanical Engineering, Univ. So. Calif., Los Angeles, Calif. E. K. Springer, T. T. Eyre.

BONE, HAROLD K., Assistant Professor of Engineering Drawing, Univ. of Okla., Norman, Okla. F. S. Roop, R. V. James.

BYERS, NORMAN R., Instructor in Machine Design, Kansas State College, Manhattan, Kansas. J. N. Wood, R. F. Morse.

CHEADLE, J. N., Instructor in Electrical Engineering, S. D. State College, Brookings, S. D. E. E. Johnson, W. H. Gamble.

CLARK, JOHN R., Assistant Professor of Electrical Engineering, Purdue Univ., Lafayette, Ind. L. E. Beck, D. T. Canfield.

DAASCH, HARRY L., Prof. and Chairman, Dept. Mech. & Ind. Eng., Univ. of Kansas, Lawrence, Kansas. Re-admission.

DELEE, JOHN L., Assistant Professor of Engineering Drawing, Rensselaer Poly. Inst., Troy, N. Y. H. B. Howe, H. O. Sharp.

DREHER, GEORGE K., Executive Director, Foundry Educational Foundation, Cleveland, Ohio. P. E. Kyle, F. H. Rhodes.

FARRAR, CLYDE L., Professor of Electrical Engineering, Univ. of Okla., Norman, Okla. F. S. Roop, R. V. James.

FONER, DAVID N., Instructor in Civil Engineering, Swarthmore College, Swarthmore, Pa. S. B. Lilly, S. T. Carpenter.

FRASH, EDWIN S., Assistant Professor of Mechanical Engineering, Univ. of Florida, Gainesville, Fla. F. H. Pumphrey, Jos. Weil.

GERHARD, SHERMAN L., Assistant Professor of Physics, Newark College of Eng., Newark, N. J. P. O. Hoffmann, F. D. Carvin.

GRAY, CHARLES H., Head, English Dept., Rensselaer Poly. Inst., Troy, N. Y. F. Abbuhl, J. R. Gould.

HAWK, HAROLD W., Instructor in English, University of Colorado, Boulder, Colo. W. O. Birk, C. L. Eckel.

HAWKINS, HAROLD V., Professor of Civil Engineering, Ill. Inst. Tech., Chicago, Ill. E. I. Fiesenheiser, P. C. Huntly.

HECKER, CHARLES H., Professor of Chemical Engineering, Clarkson College of Tech., Potsdam, N. Y. J. H. Daves, W. H. Allison.

HOUGHTON, RICHARD W., Instructor in Electronics, Wentworth Institute, Boston, Mass. M. N. Anlin, C. W. Tudbury.

KEZIOS, STOTHE P., Instructor in Mechanical Engineering, Ill. Inst. Tech., Chicago, Ill. R. A. Budenholzer, R. L. Rose.

LANGFORD, JOSEPH W., Assistant Professor of Electrical Engineering, Univ. of Mass., Amherst, Mass. G. A. Marston, J. D. Swenson.

LIVINGSTON, NOYES B., Assistant Professor of Engineering, Texas College of A. & I., Kingsville, Texas. F. W. Dotterwert, E. Koryes.

LOTHERS, JOHN E., Professor of Architecture, Okla. A. & M. College, Stillwater, Okla. R. G. Saxton, R. L. Flanders.

LUCAS, JAMES H., Associate Professor of Civil Engineering, Georgia School of Tech., Atlanta, Ga. T. H. Evans, J. M. Smith.

MASON, JAMES H., Lecturer in General Engineering, Univ. So. Calif., Los Angeles, Calif. D. M. Wilson, A. Hansen.

MAXEY, RUSSELL B., Associate Professor of Civil Engineering, Univ. of So. Car., Columbia, S. C. C. R. McMillen, R. L. Sumwalt.

MCFARLAND, DALTON E., Instructor in Engineering Administration, Mich. College M. & T., Houghton, Mich. S. R. Price, E. J. Townsend.

MEANS, R. E., Professor of Architecture and Civil Eng., Okla. A. & M. College, Stillwater, Okla. E. R. Stapley, R. L. Flanders.

MILLER, CHARLES M., Professor of Engineering, University of Wichita, Wichita, Kansas. L. E. Conrad, R. F. Morse.

MOBLEY, GORDON S., Assistant Professor of Civil Engineering, Univ. of Florida, Gainesville, Fla. C. D. Allen, F. H. Pumphrey.

MONK, CLARENCE B. Instructor in T. & A. M., University of Illinois, Urbana, Ill. W. M. Lansford, W. L. Collins.

OWEN, WILLIAM S., Dean of Faculty, Professor Naval Arch., Webb Inst. of Naval Arch., New York City. L. J. Ballard, E. H. Young.

POWERS, DEAN A., Assistant Professor of Electrical Engineering, Univ. of Toledo, Toledo, Ohio. E. O. Scott, J. B. Brandberry.

RICE, PERCIVAL S., Assistant Professor of Civil Engineering, Tufts College, Medford, Mass. E. F. Littleton, W. E. Farnham.

SCHLEMMER, ALFRED E., Instructor in Mechanical Engineering, Okla. A. & M. College, Stillwater, Okla. R. R. Irwin, E. R. Stapley.

SMITH, THOMAS N., Instructor, Mich. College M. & T., Houghton, Mich. S. R. Price, E. J. Townsend.

SNOWDEN, JAMES R., Assistant Instructor, T. & A. M., University of Illinois, Urbana, Ill. W. J. Worley, J. O. Draffin.

SPIELMAN, MAURICE, Instructor in Mechanical Engineering, Ill. Inst. of Tech., Chicago, Ill. R. A. Budenholzer, J. C. Peebles.

STEELE, ROBERT R., Instructor in Engineering Drawing, Tufts College, Medford, Mass. E. F. Littleton, W. E. Farnham.

STEEN, G. PERRY, Associate Professor of Civil Engineering, Univ. of N. M., Albuquerque, N. M. M. C. May, Roy Taft.

THOMAS, JOHN H., Assistant Professor of Mechanical Engineering, Univ. of Okla., Norman, Okla. F. S. Roop, R. V. James.

TUMA, GERALD, Assistant Professor of Electrical Engineering, Univ. of Okla., Norman, Okla. F. S. Roop, E. F. Dawson.

TURKINGTON, DONALD B., Assistant Professor of Mechanical Engineering, Univ. of Okla., Norman, Okla. F. S. Roop, R. V. James.

WISE, EDWIN M., Manager, Apparatus Dept., General Electric Co., Houston, Texas. J. M. Waters, L. B. Ryon.

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